ENHANCING THE PEDAGOGICAL PRACTICE OF SOUTH AFRICAN PHYSICAL SCIENCES TEACHERS IN INQUIRY-BASED TEACHING THROUGH EMPOWERMENT EVALUATION

By

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DECLARATION

I declare that the work contained in this dissertation is my own and all the sources I have used or quoted have been indicated and acknowledged by means of references. I also declare that I have not previously submitted this dissertation or any part of it to any university in order to obtain a degree.

Signature:

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ABSTRACT

The purpose of this study was to capture, portray and develop the pedagogical practice of Physical Sciences teachers in inquiry-based teaching using an empowerment evaluation approach. This mixed methods design study is a multiple case study in inquiry-based teaching of three Physical Sciences teachers in South Africa. This research intended to help answer the question: How can an empowerment evaluation approach influence and shift the practice of Physical Sciences teachers towards an inquiry-based pedagogy? The objectives of the study were: (a) to establish the current pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching, (b) to determine the challenges experienced by Physical Sciences teachers in implementing an inquiry-based teaching approach, and (c) to examine shifts in the pedagogical practices of Physical Sciences teachers in inquiry-based teaching using an empowerment evaluation approach. The data collection methods were semi-structured interviews, classroom observations and the Pedagogy of Science Teaching Test - Physical Sciences (POSTT-PS) instrument. Baseline results from the first phase of the study revealed that teachers in township schools practiced predominantly structured investigations when doing practical work. Another finding in this phase was that teachers prioritize the data collection phase in inquiry over other stages during their inquiry-based teaching. The research revealed that inquiry-based teaching in township schools is hampered by a lack of resources, unprepared learners, insufficient time and the pressure of summative assessments. The teachers were eager to shift their pedagogical practice to that of inquiry. In phases two and three, an empowerment evaluation approach was applied to support teachers in shifting their practices towards inquiry-based teaching. Empowerment evaluation is the use of evaluation concepts, techniques, and findings to foster improvement and self-determination (Fetterman, 2001:3). It focuses on helping people help themselves and improve through self-evaluation and reflection. The use of self-evaluation as a means of assisting teachers to improve their pedagogical practices provides a non-threatening environment for reflection and experimentation. Empowerment evaluation allows the participating teachers to craft a solution to their local challenges. Over a longitudinal period, the study revealed shifts in each of the following teacher practices: (i) pedagogical orientation, (ii) teacher's role in class, (iii) classroom discourse, (iv) teacher support, (v) teacher control, (vi) the understanding of inquiry-based teaching when given collegial support in the form of critical friendship within the empowerment evaluation approach. The study provides evidence to support the need to include reflection and immediate classroom practice opportunities within professional development models in inquiry-based teaching. The findings also reveal that through empowerment evaluation, teacher practices in the classroom can shift towards an inquiry-based approach. These findings invite reflection and review of existing professional development models, with a view to incorporating elements of empowerment evaluation.

Keywords: inquiry-based teaching, pedagogical practice, professional development, Empowerment evaluation.

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CHAPTER 1: INTRODUCTION TO THE STUDY

1.1 Introduction

This research study investigates the use of empowerment evaluation in supporting in-service science teachers from township schools in South Africa to shift towards inquiry-based teaching. The term ‘township’ usually refers to underdeveloped urban areas that, from the late nineteenth century until the end of apartheid, were set aside for non-whites (Ramnarain & Schuster, 2014). Township schools are schools servicing those locations and are sometimes under-resourced and lack basic infrastructure.

1.2 Background to the Study

In South Africa, the legacy of apartheid policy has been the diverse educational landscape. There is an enormous diversity of schools in terms of the availability of physical resources. The previous apartheid education system had policies that resulted in the inequitable distribution of resources. The legacy of these policies is most visible in the school infrastructure (Ramnarain, 2016), where there is a vast difference between a suburban (former model C) school and a township school or rural school. According to the apartheid legislation, suburban and city schools were previously designated for white learners, while township and rural schools were occupied by black learners. Township schools suffered the most from these policies and have remained poorly resourced, with scant facilities for practical work in science. Attempts to redress the situation have been made by the new government since 1994, but the inequalities of nearly fifty years created a huge gap between the former model C schools and township schools. The efforts made to redress are notable, but the improvements may be insufficient to address the huge gap that was created by apartheid policies. One of the notable efforts was the government’s response to the shortage of qualified teachers. The government gave a firm mandate to train more teachers and provide additional training to those already in service (Ramnarain, 2013). Institutions introduced a programme like the Advanced Certificate in Education (ACE) to enable teachers to develop their competencies. This was to overcome the shortage of Physical Sciences teachers as well, although ACE catered for other subjects.

A causal relationship has been established where there is a direct relationship between a nation's wealth and its scientific and technological capacity. South Africa is one nation that has largely depended on importing foreign scientific and technological expertise due to the acute skills shortage (Mateus, Allen-Ile & Iwu, 2014). To address the acute shortage of skills and redress the unequal access to science education, there is a need to increase the opportunities for the previously disadvantaged to experience quality science teaching. A study by Ramnarain and Schuster (2014) has found different teaching orientations between the teachers at township schools and suburban schools. Teachers at township schools were found to have a strong active direct teaching orientation, involving direct exposition of science associated with confirmatory practical work and their counterparts at suburban schools exhibited a guided inquiry orientation, with concepts being developed through the guided exploration phase. This difference in the way science is presented to different groups can be viewed as perpetuating the inequalities between diverse groups of learners. In South Africa, suburban schools still have a relatively small number of black learners compared to township schools that are attended almost exclusively by black learners. Any disparities that exist in the provision of education between the township and suburban schools in South Africa translate into racial division in education. The new government managed to combine the previously racially divided educational departments and provided a framework for the transformation of the education system. The framework formed part of The Department of National Education (1994) White Paper 1 on Education and Training. The framework emphasized the need to improve the school science for black learners so that strides towards equity are made (Ramnarain, 2011).

In South Africa, black learners are in the majority and are mainly 'concentrated' in township schools. Improving the quality of teaching and learning towards inquiry in township schools in South Africa would be in agreement with the reform initiatives worldwide as well as the national standards. South Africa, as a nation, needs to increase the number of learners that take up science careers. There are many ways this can be achieved and improving the quality of teaching and learning of science can be one of the ways. Physical Sciences is a key subject among the sciences at

Further Education and Training (FET) and increasing the number of learners successfully taking Physical Sciences at FET may later translate into more learners taking up science careers. All learners do Natural Sciences in the General Education and Training (GET), whereas only a small percentage of learners choose to do Physical Sciences in the Further Education and Training phase (FET) (Department of Education, 2001). The GET in South Africa is from grades seven to nine, which is the early secondary school and the FET phase is grades ten to twelve. The need to attract and retain more learners to the Physical Sciences calls for quality science teaching in all schools, but learners from disadvantaged communities such as townships have performed badly compared to learners from advantaged communities (Van Der Berg & Burger, 2003).

In light of the above, it is important that the teaching of the Physical Sciences in South African township schools improves. A key curriculum goal in school science education in many countries has been to encourage science teachers to use an inquiry-based approach to their teaching, as a means to develop learner understanding of science concepts (Ramnarain, 2015). Scientific inquiry has been advocated as a common curriculum goal in science education in South Africa and this imperative is expressed in the new Curriculum and Assessment Policy Statement (CAPS) document (Ramnarain, 2016). To this end, every teacher is expected to use inquiry when teaching science (Department of Education, 2002).

The theme of teaching science as inquiry probably dates back to the Heuristic Movement of the late 19th century but became a global phenomenon after the launching of Sputnik in 1957. This approach to teaching has its philosophical and theoretical roots in the work of Jean Piaget, John Dewey and Lev Vygotsky (Doolittle & Camp, 1999). Inquiry teaching is the pedagogical approach that models aspects of scientific inquiry (Bybee, 2004). A central aim of inquiry teaching is to develop learners' intellectual autonomy thus the teacher's role as expert shifts to that of facilitator or catalyst for learners' learning (National Research Council(NRC), 1996). Inquiry-based teaching, in this sense, is not merely a pedagogical technique but also entails a deep change in values embodied in education. Underlying this new pedagogy is the assumption that science education is not merely about knowledge acquisition, but understanding how scientific knowledge is generated, evaluating knowledge claims and conducting scientific research. In this manner, science education is more than inculcating “what we know”; it should also give learners a sense of “how we know” and “why we believe what we know over alternatives” (Duschl & Duncan, 2009).

According to the Inter-Academy Panel (IAP) (2006:6), “Inquiry-based science education is in practice when: learners are developing concepts that enable them to understand the scientific aspects of the world around them through their own thinking, using critical and logical reasoning about evidence that they have gathered.” This may involve them in firsthand manipulation of objects and materials and observation of events; it may involve them in using evidence gained from a range of information sources, including books, the internet, teachers and scientists. Teachers are leading learners to develop the skills of inquiry and an understanding of scientific concepts through the learner’s own activity and reasoning. This involves facilitating group work, argumentation, dialogue, and debate, as well as providing a direct exploration of and experimentation with materials.

Inquiry-based teaching has several benefits and these include improved achievement, knowledge application, thinking and problem-solving skills, and attitudes toward learning (Saunders-Stewart, Gyles & Shore, 2012). Studies have reported that inquiry-based learning experiences enhance learners’ motivation to learn science (Crawford, 2012), improve understanding of concepts (Gott & Duggan, 2002), facilitate collaboration between learners (Hofstein & Lunetta, 2004), and help develop processing skills (National Research Council, 1996). The South African science curriculum advocates an inquiry-based approach to practical work that encourages exploration, data collection and drawing conclusions with accuracy (Department of Education, 2002). However, despite the many benefits of inquiry-based teaching in literature and the calls to implement inquiry-based teaching in their classrooms, teachers struggle to implement reform-based approaches to teaching science (Lebak, 2015).

Research worldwide has shown that inquiry-based teaching is underplayed. In the United States, Capps and Crawford (2013) found little evidence of inquiry in classrooms of even highly motivated, well-qualified science teachers. In South Africa schools inquiry-based teaching is only sparsely evident (Ramnarain & Schuster, 2014). This suggests the dominance of the traditional teaching methods that are full of rote learning and memorization of content. This may possibly be attributed to the fact that many teachers have little knowledge of inquiry-based teaching or training in how to implement inquiry in the classroom (Bybee, 2004). Furthermore, many in-service teachers have had little or no experience as learners in inquiry-oriented classrooms. Thus, they are asked to implement a strategy that is an abstract construct to them, rather than something they have personally experienced (Lotter, Harwood & Bonner, 2006). Other cited possible factors hindering inquiry implementation at grassroots were large classes, the physical condition of many schools, the social environment of many pupils, teachers' inadequate training in National Curriculum Statement and a lack of teacher commitment (Webb & Glover, 2004). In light of this, there is an increasing need for teacher learning and development in order to develop a teaching faculty capable of actively organizing learner inquiry and active learning (Xu, 2002). Teachers are the main agents for change and are pivotal for the success of any reform effort in school (Darling-Hammond & Bransford, 2006). It is therefore important that the teacher's ability to facilitate inquiry learning effectively is enhanced. Professional development programmes focusing on inquiry-based teaching have reported positive findings (Lotter, Harwood & Bonner, 2006; Luft, 2001; Caton, Brewer & Brown, 2000). These successful inquiry-based programmes share many attributes, such as contextual relevance and sustainability, with empowerment evaluation that forms the focus of this study.

This study examined the shifts in individual teacher's pedagogical practice after undergoing an empowerment evaluation programme in the inquiry-based teaching of science. Empowerment evaluation is the use of evaluation concepts, techniques, and findings to foster improvement and self-determination (Fetterman, 2001:3). Empowerment evaluation may be the approach that can be exploited in South African schools to facilitate on-the-job, self-initiated professional development that is environmentally aware and ongoing. It focuses on helping people help themselves and improve through self-evaluation and reflection. The use of self-evaluation as a means of assisting teachers to improve their pedagogical practices provides a non-threatening environment for reflection and experimentation. Empowerment evaluation allows the participating teachers to craft a solution for their local problem. Empowerment evaluation commences with taking stock (Fetterman, 2002), an assessment of the teacher’s pedagogical practices (their teaching methods and preferences). By taking stock, a baseline is established to measure future progress. This is followed by setting realistic and immediate goals, where there is a consensual agreement between the teacher and the researcher. The goals must be linked to the teacher’s daily activities. Individuals will set their goals taking into consideration factors such as initial conditions, motivation, resources and programme dynamics. The third step will involve participating teachers selecting and developing strategies to accomplish the set goals. This is achieved through the process of brainstorming, critical review and consensual agreement (Fetterman, 1994:309). The final step was helping the teacher determine the type of evidence required to document progress credibly toward their goals. Fetterman (2001b) outlined five facets of empowerment evaluation namely training, facilitation, advocacy, illumination, and liberation. Advocacy entails helping evaluees use credible data to present their case in an evaluation of their curricula. Illumination is an eye-opening and enlightening experience that brings about new insight or understanding about an issue or practice. Liberation follows illumination, and is the act of freeing oneself from preexisting roles and constraints, contributing to self-determination.

1.3 Rationale

After attaining its independence in 1994, the new government of South Africa needed to design what is considered a more inclusive and culturally sensitive curriculum than that of the previous government. The advent of the Revised National Curriculum Statement (RNCS) signalled sweeping curriculum reform for grades R–9 (reception year to grade 9). In 2006, the National Curriculum Statement (NCS) at the Further Education and Training (FET) phase (grades 10-12) was launched. The RNCS and NCS emphasized the need for teaching and learning of science through inquiry. The year 2011 saw the merging of the two National Curriculum Statements, for grades R-9 and grades 10-12 to form the National Curriculum Statement (grades R-12) (Department of Basic Education, 2011). The National Curriculum Statement comprises three policy statements, one of which is the Curriculum and Assessment Policy Statement (CAPS). Specific Aim One of the CAPS underlines an inquiry-based pedagogy by stating that "the purpose of Physical Sciences is to make learners aware of their environment and to equip learners with investigating skills relating to physical and chemical phenomena" (Department of Basic Education, 2011:8).

According to Chisholm (2005), South Africa has given science an uncontested primacy of place in the curriculum. We have witnessed many initiatives in South Africa: OBE, Curriculum 2005 and NCS. These curriculum changes mirror worldwide reform trends in science education (Ramnarain & Schuster, 2014). While the goal of every reform initiative is to improve learner learning and performance, the success thereof is linked to the recognition of the critical position of the teacher in raising learner performance. A study conducted in South Africa (Maree & Fraser, 2004) show that teachers continue to use traditional methods of teaching even if the policy encourages inquiry-based teaching. A study by Ramnarain and Schuster (2014) found that teachers at township schools have a strong 'active direct' teaching orientation, involving direct exposition of science. If the current situation in the township schools has to change, there is a need for teachers to develop appropriate competencies to implement inquiry strategies.

There have been strong support and recommendations from researchers and curriculum documents for inquiry-based instructional strategies and models to teach science (Lotter et al., 2016). Despite these imperatives, the situation at the level of the classroom remains unchanged, with teachers enacting predominantly teacher-centred pedagogies. Ramnarain, (2010a) revealed that in South African schools where science investigations are taking place, investigations are mainly structured investigations with the teacher exercising a great deal of control during all stages of the investigation. Several studies (Van Driel, Verloop & De Vos, 2001; Windschitl, 2002) report difficulties teachers have with incorporating inquiry in science education and it was of paramount importance to bridge the gap between theory and practice by initiating a shift towards inquiry-based teaching. This study seeks to explore these possibilities of scaffolding inquiry-based teaching through teacher support. Teachers determine what is taught in the classroom and how it is taught, making them a critical factor in learners' learning (Abell, 2007). Many studies have pointed out much of the problems of traditional methods and the opportunities offered by inquiry-based teaching (Saunders-Stewart, Gyles & Shore, 2012), but very few alternatives have been pursued to try and change what is happening in the classroom (Lotter, Harwood & Bonner, 2007). If there is going to be changed in teacher practice, a professional development programme that gives opportunities to participants to practice what they learn is needed. Our problem as a nation is not that we do not have professional development programmes, but that many of them could be failing to achieve the intended results. Some of the weaknesses of the professional development programmes from literature include an unfavourable training method (Hopkins, Harris, Singleton & Watts, 2000) and use of a top-down approach when having teachers participate in the programme (Desimone, 2009). The process of acquiring the appropriate competencies places new demands on the professional development of science teachers both pre- and in-service. In this study, teachers develop their own knowledge and skills necessary for teaching Physical Sciences using inquiry-based teaching approach in South Africa.

1.4 Research Aim, Question and Objectives

The aim of this study was to capture, portray and develop the pedagogical practice of Physical Sciences teachers in inquiry-based teaching using an empowerment evaluation approach. This research study was designed to answer the research question: How can an empowerment evaluation approach influence and shift the practice of Physical Sciences teachers towards an inquiry-based pedagogy? Linked to the research question were the objectives to the study. The objectives are as follows:

1. To establish the current pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching.

2. To determine the challenges experienced by Physical Sciences teachers in enacting an inquiry-based teaching approach.
3. To examine shifts in the pedagogical practices of Physical Sciences teachers in inquiry-based teaching following an empowerment evaluation approach.

1.5 Research approach

This study adopted an exploratory case study approach. Case studies are detailed investigations of individuals, groups or institutions within their own unique context (Patton, 2002). Yin (2003:13) described the case study through the lens of the research process as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident". Opie (2004:74) views a case study as "an in-depth study of interactions of a single instance in an enclosed system". This study focused on three participants, with each participant constituting an individual case. Hence, this study constitutes a multiple-case design (Yin, 2003). Yin (2004:5) maintains that in a multiple-case design "the data from multiple cases can strengthen your case study findings and make your interpretations more robust".

Three Physical Sciences teachers from a district in Gauteng province were selected for this study. Purposive and convenience sampling was used in choosing these teachers. Purposive in the sense that the researcher selected teachers from which the most can be learned (Merriam, 1998) and convenience because they were accessible in terms of travel time and distance. The three Physical Sciences teachers were eager to shift their practice towards an inquiry-based pedagogy.

Data were collected from multiple sources including, Pedagogy of Science Teaching Test (POSTT-PS) instrument, classroom observations, stimulated recall informal discussions, and semi-structured interviews. Data collection was according to the four steps of empowerment evaluation (Fetterman, 2002). In 'taking stock', data on the pedagogical orientation of the teachers was collected. An instrument called the POSTT-PS was administered (Ramnarain & Schuster, 2014). The test consists of case-based objective items based on realistic vignettes of classroom teaching situations on science topics. A typical item presents a realistic teaching scenario for a science topic, poses a question about teaching strategy, and offers response options reflecting a spectrum of teaching orientations ranging from direct instruction through guided inquiry to open inquiry. Quantitative data in the form of responses to POSTT-PS were analyzed statistically to establish the teachers' pedagogical orientation. In interviews, the teachers were probed on their responses to POSTT-PS. The interviews were recorded and later transcribed. A baseline classroom observation of each teacher was done and a video was recorded to aid stimulated recall informal discussions. An open coding of the data was first completed, looking for reasons that could explain the option chosen on the test. The codes were then grouped into code families that could form themes (Creswell, 2007) on factors that influence the pedagogical orientation of teachers.

Once the pedagogical orientation of the teacher was established, a meeting was set with him or her to formulate goals relating to teaching practice. Strategies were then developed in the second meeting on how these goals were to be met. A third meeting was scheduled to identify the type of evidence required to document credible progress towards their goals. All discussions with the teachers during these two stages were recorded and later transcribed.

In documenting progress, data were collected by observing lessons. A brief discussion with the teacher on the lesson planning was done before each lesson. These lessons were video recorded. After each lesson, stimulated recall discussions were held with the teacher in enabling the researcher the opportunity to see the classroom practice through the teacher's eyes. The discussions were centred on the following: the objectives of the lesson, assumptions on which the lessons were based, plan/design of the lessons and activities during the lessons. The discussions were recorded and transcribed.

The data was analysed in order to find evidence relating to the facets of empowerment evaluation already described. Based on this analysis themes were developed. For example, with regard to facilitation, I highlighted my role in the stimulated recall discussions with the teacher in order to enable the teacher to reflect on his or her practice in relation to the advancement of the pedagogical goals that had been set. The process of change in the pedagogical practice of the teachers was analysed in terms of the Interconnected Model of Professional Growth (IMPG) (Clarke & Hollingsworth, 2002). According to this model, the teacher's world is made up of four distinct domains that change through the processes of reflection and enactment. The teacher's initial knowledge (pedagogical knowledge, knowledge of inquiry and knowledge of how to implement it in class) gathered from the instrument, POSTT-PS, first interview and classroom observation constitute the personal domain for the teacher. The empowerment evaluation programme was the external domain and the teacher experimentation in the classroom was the domain of practice. The salient outcomes of the experimentation were the domain of consequences. This model was, therefore, used as an analytical tool in making the changes in the pedagogical practice of the teacher more explicit by outlining the process of change.

1.6 Outline of the thesis

Chapter One outlines the background of this study, the context in which it was conducted. It introduces the research questions and the research methods and provides an overview of a research study.

Chapter Two provides a more comprehensive literature review of the inquiry-based teaching, professional development, and empowerment evaluation.

Chapter Three gives an outline of the research design and includes reasons for each research approach and method used.

Chapter Four is a discussion and interpretation of the results from Phase One (POSTT-PS instrument and semi-structured interviews).

Chapter Five is a discussion and interpretation of the results from the intervention programme.

Chapter Six examines the results of the data analysis and findings of the research. The discussion and interpretation of the results in terms of each objective and the overall research question. It also gives the implications and conclusion.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter gives an outline of the theoretical framework and explores the major concepts shaping the conceptual framework. The literature survey of the main terms and concepts in science education is intended to operationalize them. The major terms explored and operationally defined are inquiry, inquiry-based teaching, pedagogical orientations and professional development.

2.2 Theoretical Framework

The research study was guided by two theories: social constructivism and Ausubel's learning theory. Ausubel's theory provides a framework in which we view learning in the light of pedagogical practice (Ausubel, Novak & Hanesian, 1986). His ideas, together with Vygotsky's, form the theoretical framework of this study. Vygotsky is the founding father of social constructivism and believed that social interaction is an integral part of learning. According to him, social interaction, culture and language are three variables that affect how individuals learn. Social constructivism posits that the learner's construction of knowledge is the product of social interaction, interpretation and understanding (Vygotsky, 1962). Vygotsky's theory regards collective learning as primary and individual learning as secondary. As elaborated by Daniels (2001), knowledge constructs are formed first on the inter-psychological level before becoming internalized. In this regard, learning becomes the development of personal meaning in order to produce socially agreeable interpretations. Learners who fail are said to have inadequately synthesized information and are therefore unable to convey a socially acceptable interpretation. The aim of learning is thus to become aware of the realities of others and their relationship with one's own. In social constructivism, ideas are constructed through interaction with the teacher and other learners, thus language precedes thinking (Powel, 2010). Vygotsky views the direction of the development of thinking from the social to the individual. Social constructivism has a major influence on contemporary educational theories and on many practical solutions now presented as good learning and teaching.

The social constructivist-oriented teacher is positioned as an organizer and a potential source of information. The role of the teacher is more that of a facilitator, working to provide learners with opportunities and incentives to construct knowledge and understanding. The constructivist environment advocates the gradual transference of power thus giving the learning agenda to the leaner. This does not remove the need for the teacher but redirects teacher activity towards the creation of an environment conducive to learners' knowledge construction. The teacher must allow methods that encourage the sharing of ideas resulting in the classroom becoming the 'community of practice'. Discussions are therefore important in determining whether the meaning we evoke in others is either the same or different from our own. As we evaluate each other's interpretations, we generate a variety of ideas and meanings. This, in turn, increases the probability of reaching the point where our own knowledge is unsustainable. It is suggested that learners' creation of new knowledge is promoted by encouraging them to discuss, explain and evaluate their ideas and procedures. A pupil is more likely to construct new ideas by evaluating their peers' shared or idiosyncratic views, as well as when they explain their ideas to peers. The teacher stimulates discussion and thought, thus providing opportunities for learners to scaffold their understanding. This is achieved through the use of suitably phrased, open-ended questions and tasks. This discursive nature of social constructivist learning environments emphasises the need for learners to be given time to talk. This collaborative discourse leads to opportunities to self-reflect an important factor in knowledge construction. Thus, learning involves the learner and teacher in co-constructing the social-cultural realm. Social constructivist approaches acknowledge the need for pupil interaction. The pupils are to re-contextualize the everyday knowledge they acquire at home, which thrives on naïve or idiosyncratic theorizing, into the school environment where formal theories and sense-making abound (Easen, 2005).

Social constructivist teaching strategies and practices are the next important step in educational reform. Social constructivism posits that knowledge is not located exclusively in the mind, but rather exists in people's minds and as an objective entity in social interaction. People's personally constructed ideas are constrained or modified by these externally developed social schemata. Thus, in the classroom knowledge does not exist on chalkboards, nor in books nor activities, but in the teachers' and learners' minds. The learners and teachers give meaning to the curriculum according to their existing knowledge and beliefs. The learners have fewer and/or different interrelations with the world and may construct unintended ideas or meanings which, to them, are either useful or certain. Learners in the same class experience the same world differently and normally have less interrelation with it than the teacher does. This suggests that there may be a variety of ideas among learners about a certain thing. Depending on their knowledge, teachers and pupils can generate different meanings for the same material. Teachers may need to have good subject knowledge as well as knowledge about what the learners might be thinking. This will assist them in determining how this thinking may develop to promote the creation of acceptable knowledge. For the teacher to promote the learners' creation of acceptable knowledge he or she must be able to make inferences about the alternative meanings sometimes formed by learners. Teachers and teaching methods per se do not change learners' ideas; rather change occurs from within through learners' interrelations with the world, of which the teacher is part. Learners are ultimately responsible for their learning. The same processes of construction, which function in interrelations with the world outside the classroom, also function in their interrelation with the curriculum and other learners inside the classroom. The main concept is that ideas are constructed from experience to have a personal meaning for the learner.

Constructivism, in general, is an important theoretical paradigm in science education research and has been accepted widely throughout the science education research community, as an alternative to a behaviourist view that learning is absorption and reproduction of knowledge (Malcom, 2001). According to this view, the learners are considered to be a tabula rasa, thus receiving knowledge from the teacher via carefully constructed, teacher-centred activities. The class is dominated by teacher exposition and methods of teaching that best assist learners in negotiating summative assessments designed to evaluate performance. This view normally adopts an overly simplistic causal link between outcomes on assessments and the quality of pupil learning. Such target-driven orientations equate favourable test results as the ultimate aim of education and lay the problem of underachievement squarely at the door of the teachers (Willinsky, 2005). This will then invite teaching methods that attempt to maximize marks, what could be viewed as ‘teaching to test’. Recent publications and debates attempt to reorient discussion from performance to learning (Adams, 2006).

In contrast to the behaviourist view of learning, which ignores deliberation about cognition, social constructivism acknowledges that learning occurs in the mind. It posits that existing knowledge structures and beliefs support or militate against new learning (Sherpard, 2000). This has an impact on the teaching and learning in the classroom. Constructivist teachers respect learners’ autonomous, generative processes of learning. The constructivist classrooms are characterized by non-competitive and collaborative interactions, and learners’ freedom of expression is upheld. The social constructivist paradigm explicitly and implicitly acknowledges the contingent and fluctuating nature of learning and keeps the locus of control squarely with the pupils (Watkins, 2001).

Ausubel’s ideas focus on the most important desired outcome of any type of instruction, which is ‘meaningful learning’. According to Ramnarain (2014), meaningful learning involves cognitive engagement in such a way that knowledge becomes integrated with the learner’s conceptual schemata as opposed to rote learning. Ausubel viewed learning as an active process that brings something new into our cognitive structures. Ausubel’s representation of the nature of learning and the type of instruction is shown in Figure 2.1 below.

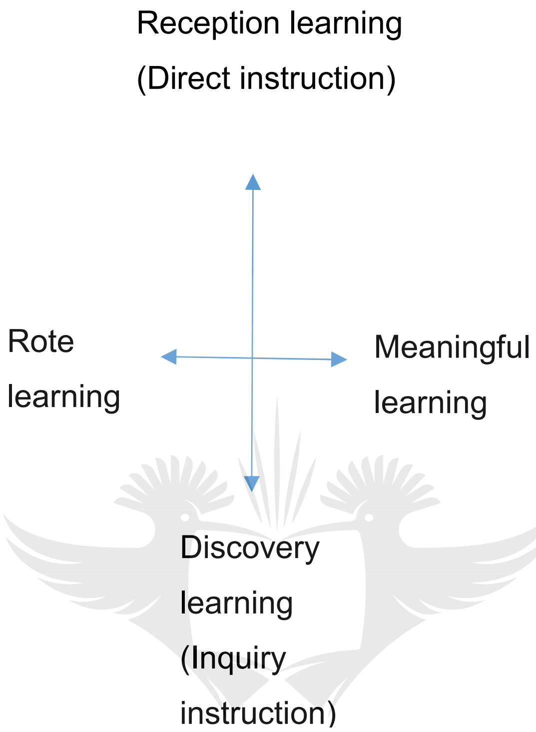


Figure 2.1: Ausubel's representation of nature of learning and types of instruction

This diagram presents the four quadrants that depict the four categories along the instructional spectrum labelled as reception and meaningful (quadrant 1), discovery and meaningful (quadrant 4), reception and rote (quadrant 2) and discovery and rote (quadrant 3). These can best be reflected in today's terms as active direct, guided inquiry, didactic direct and fragmented open inquiry respectively. According to Ausubel even direct instruction can be meaningful if well designed; and hands-on activity without cognitive engagement does not necessarily lead to meaningful learning. It is unfortunate that in many instances reception learning (direct instruction) is equated with rote learning while discovery learning is generally equated with meaningful learning (Cobern et al., 2014).

Constructivist philosophy and constructivist teaching strategies are consistent with Dewey's view that education takes place through inquiry and that education is a continuing reconstruction of experience. These teaching strategies are based on the ability of the teacher to use the learner's prior or present knowledge as the base to construct new knowledge. The prior knowledge is gathered through asking information-seeking questions. A teacher must have a commitment to learners to maintain a non-threatening, non-evaluative atmosphere in which children can express their ideas freely. As the pupils ponder on and discuss the given questions, the teacher is privileged to make inferences about the learners' ideas. It is through making inferences about the learners' ideas that the teacher facilitates and guides learning. It is the inferences that will help the teacher build his or her own hypothesis. The teacher then presents more problems or asks more questions based on this hypothesis. After presenting problems, the teachers must stand back and let learners solve them. This will provide pupils with ample opportunities to discuss, or explain and evaluate their solutions. Learners are encouraged to participate in class discussions and given the opportunity to apply their ideas in a variety of situations. Teachers must allow learners to explain honestly, openly and without risk, how they actually interpreted and solved problems. During these discussions, the teacher and pupils are encouraged to devise imaginative ways to test their ideas using appropriate materials and equipment.

Teachers must not evaluate explicitly learners' answers or challenge a pupil's ideas; there should be a shared perception. The learner must not view the teacher as an intellectual adversary, but a collaborator in the process of making new sense of the world. Teachers guide construction by providing problems and collaborating with learners during discussions. Teachers especially must not assess learners' thinking formally; rather, as a matter of course, teachers should listen and watch, generate inferences and make judgments about pupils' developing knowledge. Assessment is intrinsic to the very act of teaching and does not consist of simply checking learners' written answers. The evaluation is not about knowing where the learners are, but about deciding on activities which encourage further conceptual development. The relationship between teachers' knowledge and practice is reflexive when a teacher reconstructs knowledge from learners' thinking. This may result in the teacher developing new problems, activities and materials. Learners need to be able to trust teachers to respect their efforts. Learners need to depend on the teacher and other learners to be supportive of their ideas and believe that confusion is temporary, as construction can take time. Teacher guidance must come after inference and be non-directive. Teachers need to trust learners to solve problems rather than giving them solutions. This does not imply passivity or disengagement on a teacher's part. Learners that are more knowledgeable tend to be confident about sharing their ideas. Teachers must not rush pupils into conceptual change. Social constructivists propose that knowledge is not transmitted directly from one person to another, but is actively constructed by the learner. Learners construct new knowledge in perceiving and acting on things in the classroom and through interaction with the teacher and others. Teachers are to facilitate learners' reconstruction of their everyday knowledge through the provision of a supportive classroom atmosphere. The learner must be free to take the risk; to restructure confidently, and sometimes excitedly, their ideas or procedures. The teacher must present problems which may be solved in different ways and allow the learner to explain and justify their solutions. The focus must not be on learners' correct answers or responses, but on devising activities to test their own ideas.

2.3 Conceptual Framework

Inquiry has become a perennial and central term in the rhetoric of past and present science education reforms (Abd-El-Khalick et al., 2004). Despite currently being one of the most used terms in science education, there is much confusion in general about what constitutes an inquiry and its role in science teaching (Abrams, Southerland & Evans, 2007). Various definitions of inquiry exist in science education literature (Newman et al., 2004). Although the definition of inquiry varies among science teachers, its presence is undeniable in current science education research. According to Windschitl (2002), inquiry has been a broadly defined construct in science education; however, the broader concept of inquiry has had less well-defined contours in classroom practice. Windschitl (2004) further asserts that ideas about inquiry are partly in the head (with different people understanding different aspects), partly embodied in the practices of the classroom, and partly codified in various community-wide discourses. This may have resulted in a lack of agreement on the meaning of inquiry in the field of science education (Martin-Hauser, 2002; Minstrell & Van Zee, 2000). A collective definition of inquiry refers to at least three distinct categories of activities – what scientists do (conducting investigations using the scientific methods), how learners learn, mirroring the processes used by scientists, and a pedagogical approach (Minner, Levy & Century, 2010). This could be the source of the variations in the understanding of inquiry where different scholars may define inquiry in different categories and appear to have different interpretations of the term. According to Ramnarain (2014), inquiry is a complex and multifaceted activity that involves both cognitive and physical activity. This has been highlighted in the widely quoted description given by the National Science Education Standards:

> Inquiry is a multifaceted activity that involves making observations, posing questions, examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating results. It also refers to the activities of learners in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (NRC, 1996:23).

A further explanation that captures the essence of inquiry was given by the NRC (1996, 2000); inquiry involves (a) the cognitive abilities that learners must develop; (b) an understanding of the methods used by scientists to search for the answers for their research questions; and (c) a variety of teaching strategies that help learners learn about scientific inquiry, develop their abilities of inquiry, and understand science concepts. The NRC views inquiry as an end (abilities learners develop), as a subject (understanding methods used by a scientist) and as a means (teaching strategies).

2.3.1 Inquiry as the End

Inquiry is viewed as an end - *a set of learning outcomes*. Inquiry is a science content area viewed in two perspectives: what learners should understand, namely scientific inquiry, and the abilities learners develop based on their experiences with scientific inquiry. The National Research Council published *Inquiry and the National Science Education Standards* and identified five essential features of inquiry (2000:25):

1. scientifically oriented questions that will engage the learners;
2. evidence collected by learners that allows them to develop and evaluate their explanations to the scientifically oriented questions;
3. explanations developed by learners from their evidence to address the scientifically oriented questions;
4. evaluation of their explanations, which can include alternative explanations that reflect scientific understanding; and
5. communication and justification of their proposed explanations.

Publications by the National Research Council (NRC, 2012) and Next Generation Science Standards (NGSS Lead States, 2013) use the term 'practices' instead of 'skills'. The shift of focus to science practices identified eight practices: asking questions; developing and using models; planning and carrying out investigations; analysing and interpreting data; using mathematics and computational thinking; constructing explanations; engaging in argument from evidence; and obtaining, evaluating, and communicating information (NRC, 2012:42). There is greater consensus regarding what learners should learn about scientific inquiry than how teachers should instruct learners (Anderson, 2007).

2.3.2 Inquiry as a Means

Inquiry here is viewed as a means - *pedagogical approach* (National Research Council, 2000). It includes teaching strategies associated with inquiry-oriented science activities. According to Bybee (2006), these are the pedagogical approaches that model aspects of scientific inquiry. The NRC (1996) included a list of increased emphasis and decreased emphasis regarding inquiry (Table 2.1). Barman (2002) views inquiry as a teaching strategy and a set of learned skills. As a pedagogical approach, inquiry helps learners to achieve scientific understanding. According to Anderson (2002), the last half of the 20th century associated inquiry with "good science teaching and learning''. Aspects of inquiry teaching include a strategy to assess learners’ prior knowledge and ways to utilize this information in their teaching; effective questioning strategies, including open-ended questions; and long-term investigations, rather than single-period verification-type investigations (Barrow, 2006). In a classroom where science is practised as inquiry, learners and teachers are engaged in first-hand observations of evidence, discussion of ideas, and the generation of scientific explanations based on the available evidence and theories (Kim, Tan & Talaue, 2013).

Table 2.1: Changing Emphasis to Promote Inquiry

Less emphasis on	More emphasis on
Activities that demonstrate and verify science content	Activities that investigate and analyze science questions
Investigations confined to one class period	Investigations over extended periods of time
Process skills out of context	Process skills in the context
Emphasis on individual process skills as observation or inference.	Understanding multiple process skills – manipulation, cognitive, procedural
Getting an answer	Using evidence and strategies for developing or revising an explanation
Science as exploration and experiment	Science as argument and explanation
Providing answers to questions about science content	Communicating science explanations
Individuals and groups of learners analyzing and synthesizing data without defending a conclusion.	Groups of learners often analyzing and synthesizing data after defending conclusions.
Doing a few investigations in order to leave time to cover large amounts of content	Doing more investigations in order to develop understanding, ability, values of inquiry and knowledge of science content
Concluding inquiries with the result of the experiment	Applying the results of experiments to scientific arguments and explanations
Management of materials and equipment	Management of ideas and information
Private communication of learner ideas and conclusions to teacher	Public communication of learner ideas and work to classmates

2.3.3 Knowledge about Inquiry

The third component of inquiry; knowledge about inquiry, was proposed by Lederman in 2003. Inquiry has many connotations and has been associated with a wide range of intellectual activities. In many cases questions about the natural world are posed, investigations are designed, and data collected and analyzed in order to resolve the question. It is therefore important that teachers be able to help learners understand the epistemological role of inquiry in scientific thought and to help learners become participants in the practices that characterize the discipline today (Windschitl, 2002).

2.3.4 Forms of Inquiry

There are various forms of inquiry practiced in the classroom and science education researchers have developed an inquiry index based on the degree of independence afforded to the learners. According to Abrams, Southerland & Evans (2007) the degree of inquiry depends on who is responsible for each of the three key activities (Table 2.2). The three key activities as identified by Schwab (1962) and Colburn (2000) are, asking questions, collecting data and interpreting data. At one end of this continuum are confirmation experiences or verification where learners verify known scientific principles by following a given procedure. This is what most writers identify as cookbook laboratories. Blanchard et al. (2010) call this level zero. This is followed by structured inquiry where the teacher poses a question unfamiliar to the learners and provides them with the procedure to follow. The learners are only responsible for the interpretation of the result. The second level of inquiry, guided inquiry, is characterized by the teacher providing the problem to investigate, as well as the procedures to follow in resolving the problem. How to interpret the results is left to the learners. The learners are led to an understanding of scientific concepts by performing experiments or exercises whose outcomes are already known to the teacher (Domin, 1999). At the top of the continuum lies open inquiry, which is the highest level of inquiry, where the teacher allows the learners to develop their own questions and design their own investigations. The learners, therefore, take responsibility for all major aspects of the investigation. There are reported learning benefits from the open-inquiry approach (Berg, Bergendahl, Lundberg & Tibell, 2003), despite the numerous challenges associated with its implementation: teacher preparedness (Shedletzky & Zion, 2005), teachers' fear of losing classroom control (Deters, 2004), and learners' frustration (Trautmann, Makinster & Avery, 2004). Learners' frustration may be a result of them failing to navigate some important stages in the investigation such as the initial step of generating an investigative question. The teacher may circumscribe a subject area for investigation, but crafting a question that is meaningful, consistent with existing theory and testable is complex difficult to structure (Windschitl, 2002). This may suggest that open inquiry is more challenging for learners to participate in and for teachers to facilitate. Sometimes the teacher might come in and assist learners even though the initial intention was learner autonomy. This may result in difficulties in giving clear-cut distinctions on these forms of inquiry (Blanchard, 2006).

It is important to recognize that there is no optimal form of inquiry that extends across all content or contexts (Blanchard et al., 2010). The level of inquiry employed at a particular time is dependent on many issues and these include the goals of the teacher, the teaching context, the skill level of the learners and the availability of materials. Open inquiry should, therefore, not be viewed as the ideal way to teach science (Settlage, 2007). Which approach should be used in the classroom for inquiry learning is therefore open to debate (Bunterm et al., 2014)? More studies are needed that can compare the different types or levels of inquiry and their impact on science learning. It is believed that forms of inquiry that include some explicit instructions are more effective at imparting science content knowledge and science process skills than expository laboratories (Blanchard et al., 2010) and create better learning opportunities than open inquiry does (Gaddis & Schoffstall, 2007). However, open-inquiry learners were more satisfied and believed they gained more benefits from implementing the project than the guided-inquiry learners (Sadeh & Zion, 2012).

Table 2.2 Levels of inquiry (Abrams et al, 2007) adapted from Schwab (1962) and Colburn (2000)

	Source of question	Data collection methods	Interpretation of results
Level 0: verification	Given by teacher	Given by teacher	Given by teacher
Level 1: structured	Given by teacher	Given by teacher	**Open to learner**
Level 2: Guided	Given by teacher	**Open to learner**	**Open to learner**
Level 3: open	**Open to learner**	**Open to learner**	**Open to learner**

2.3.5 Historical and philosophical origins

It is difficult to trace exactly the first appearance of inquiry instruction (Minner, Levy & Century, 2010). It may be said that inquiry originated from the longstanding dialogue about the nature of teaching and learning as early as the works of Piaget, Vygotsky and Ausubel. These theorists have contributed much to the building of the philosophy of learning known as constructivism (Cakir, 2008). Constructivism maintains that scientific knowledge is socially constructed and facts are made by individuals (Atherton, 2009). This means an individual needs to be actively engaged both behaviourally and mentally in the learning process for learning to take place. Constructivist approaches emphasize that knowledge is constructed by an individual through active thinking, defined as selective attention, an organisation of information and integration with or replacement of existing knowledge (Cakir, 2008; Mayer, 2004). The constructivist approach became particularly prominent in science education through the focus on inquiry.

According to Dow (1999) inquiry has its deeper roots in the Socratic inquisitiveness of Athenian times. In support of this view, De Boer (2006) argue that, in one form or another, inquiry teaching has been part of the educational landscape since time immemorial. One of the greatest philosophers of all time, Aristotle, saw inquiry as a persistent examination of the nature of mind. Aristotle believed that abstract knowledge was possible but was obtained from experience in accordance with the rules of logic. His philosophy is the root of empiricism. Empiricism holds that valid knowledge is knowledge based on experience and sensual data.

In 1620, Bacon proposed induction as the logic of scientific discovery and deduction as the logic of argumentation (Malhotra, 1994). According to Bacon, it was important that scientists observe nature without preconceptions, and use inductive logic to make generalizations from observation (Martin, 1992). His works established deductive methods for scientific inquiry, often called the scientific method. Historically the practice of scientific inquiry was associated with a procedural following of a so-called scientific method. Today we know that scientific inquiry is a much more complex activity involving a variety of processes which can be carried out in various non-procedural ways. As Windschitl (2004) indicated, the scientific method is often portrayed in textbooks as a linear procedure; however, this characterization and the label itself are misrepresentations.

In 1916, Dewey (a former science teacher) proposed that learners be taught in such a way that the learners themselves add to their personal knowledge of science. It is his model which was the basis for the Commission on Secondary School Curriculum, (1937) entitled *Science in Secondary Education*. According to Dewey (1938), problems to be studied must be related to learners' experiences and within their intellectual capability. The inclusion of inquiry in the K-12 science curriculum in the United States of America was recommended by Dewey. According to Barrow (2006), Dewey considered that there was too much emphasis in science on facts rather than thinking. Dewey then encouraged the science teachers to use a rigid scientific method in which the learner is actively involved and the teacher has a role as facilitator and guide. This suggests that Dewey wanted the learners to be active learners in their searching for answers.

In 1957, Russia launched the Sputnik and this caused the Americans to question the quality of US science teachers and the science curriculum. Initiatives were taken and to provide for the development of a curriculum, and accompanying professional development, with the emphasis on thinking like scientists (De Boer, 1991). The National Science Foundation (NSF) funded a number of initiatives, including the Physical Science Study Committee of 1960. In the same year, Schwab described two types of inquiry; stable (growing body of knowledge) and fluid (invention of conceptual structures that revolutionize science). Rutherford (1964) considered inquiry as both content and concepts that are to be understood in the context of how they were discovered. He recommended that all science teachers have a background in the history and philosophy of science.

According to Schwab (1966), learners were to view science as a series of conceptual structures that should be continually revised when new information and evidence was discovered. Schwab considered that science should be taught in a way that was consistent with the way modern science operates, encouraged teachers to use the laboratory in the teaching of science concepts and recommended that science be taught in an inquiry format. Schwab also identified another form of inquiry and he called this inquiry into inquiry (Duschl & Hamilton, 1998). Here learners could use and read reports or books about research and have discussions about problems, data, the role of technology, the interpretation of data, and any conclusions reached by scientists.

In 1981 Project Synthesis, a compilation of the major National Science Foundation (NSF) projects, was launched. Inquiry was one of the five areas of Project Synthesis (Welch, Klopfer, Aikenhead & Robinson, 1981). Inquiry was viewed from two perspectives: content for teachers and their learners and the strategy used by science teachers to help their learners learn science. The Project Synthesis report divided the learner outcomes for inquiry into three categories (science process skills, nature of scientific inquiry and general inquiry processes). The early challenges were limited teacher and school management preparation, lack of time, limited available materials, lack of support, emphasis on only content, and difficulty teaching (Welch, Klopfer, Aikenhead & Robinson, 1981). To address these and many other challenges, several projects were initiated and documents were published. Among many other documents published, were the National Science Education Standards (NSES) and Project 2061.

Project 2061, by the American Association for the Advancement of Science (AAAS), produced their first document, Science for all Americans (SFAA), which established goals for teaching inquiry. They considered inquiry as a science content topic and had the following recommendations: start with questions about nature, engage learners actively, concentrate on the collection and use of evidence, provide historical perspective, insist on clear expression, use a tea approach, do not separate knowledge from finding out, and deemphasize the memorization of technical vocabulary. A second policy document, the National Science Education Standards (NSES) (NRC, 1996) considered inquiry as the overarching goal of scientific literacy. The NSES goes beyond Project 2061 in describing inquiry. In a nutshell, the NSES defined inquiry as content, process skills and teaching strategies.

2.4 Inquiry-based Teaching

Inquiry-based teaching is a learner-centred method of teaching science that is aligned with constructivism. There are many definitions of inquiry-based teaching. Colburn (2000) defined inquiry-based teaching as the creation of a classroom where learners are engaged in essentially open-ended, learner-centred, and hands-on activities. The type of activities that the learners do in inquiry-based learning is close to what scientists do in the real world (Martin-Hauser, 2002), and these include asking questions about the world around them, gathering evidence and providing explanations. Some of these activities may not necessarily be hands-on as suggested by Colburn and certainly certain hands-on activities cannot be referred to as inquiry if they are conducted in the absence of research questions (Bell, Smetana & Binns, 2005). Actually, in terms of activities in the classroom, it is generally agreed that activities do not equate to inquiry. This suggests that inquiry-based teaching is more than what happens in the classroom or what materials are used, but a way of doing things that is grounded in a deep desire to do science the way scientists do.

Kim, Tan & Talaue (2013) write that, in practicing science as inquiry, learners should be provided with opportunities to gather evidence, decide on the value of the evidence, and craft coherent scientific explanations based on the available evidence. The teaching of science should place scientific explanations at the centre of scientific knowledge and the understanding of the process of science. An attempt has been made by recent research to better conceptualize the components of scientific explanations (Braaten & Windschitl, 2011). An important characteristic of scientific explanations would be the incorporation of theories and theoretical models to account for the observations made in nature.

The use of inquiry-based approaches is strongly advocated for the teaching and learning of science (Minstrell & Van Zee, 2000; National Research Council, 2000). Current science education emphasizes scientific knowledge as a process (science in the making) more than scientific knowledge as a product (ready-made science). Science curriculum documents have stressed the need for helping the learners appreciate the process by which scientific content is generated and understand the rules for generating and evaluating scientific knowledge. The most promising means to achieve this goal has been science as inquiry. Inquiry-based science has since been widely emphasized among science teachers and has become the central part of the science curriculum for the twenty-first century in many countries (Abd-El-Khalick et al., 2004). Inquiry-based science is seen as a means to present more accurate ideas about science as a discipline and, more so, as a way of knowing (Kim, Tan & Talaue, 2013). The increasing emphasis that has been placed on inquiry has taken science teaching beyond learner acquisition of content knowledge to teaching skills and ways of processing information that will answer their everyday challenges (Kolsto, 2001). Inquiry-based science is envisaged as a means, as well as an end, to science curriculum change. An effective way of presenting science as inquiry would be through inquiry-based teaching.

Inquiry-based instruction is promoted in national reform documents as an effective way to help learners learn science content, comprehend the nature of scientific inquiry, and understand how to engage in the inquiry process (AAAS, 2000; NRC, 1996). The reform documents indicate that teachers need to spend more time using inquiry-based instructional strategies and less time in didactic presentations of facts (Gess-Newsome, Southerland & Johnston, 2003). Although the science education documents advocate inquiry-based teaching, in practice, one finds a variety of science instructional approaches (Ramnarain & Schuster, 2014). The state of affairs in many schools is that most teachers appear to have difficulty creating classroom environments that are inquiry-based (Minstrell & Van Zee, 2000). The complexity of teaching science as inquiry in a school setting, and the demands on a teacher to take on a myriad of roles may be important reasons why this kind of teaching is so rare (Crawford, 2000; Windschitl, 2003). Research has not provided a clear picture of just how difficult it is to teach inquiry-based science (Anderson, 2002), but researchers have identified factors such as class size, availability of resources, teacher competence and confidence, time constraints, learner ability, school culture, parents' expectations, high stakes testing, and the nature of prior authentic scientific research experiences (Crawford, 2007; Kim & Tan, 2011; Ramnarain & Schuster, 2014; Windschitl, 2003). Recent science education literature promotes inquiry-based instruction in the classroom. Researchers argue that inquiry-based teaching is better aligned with how people learn and should result in a better understanding of scientific content and processes for a greater diversity of learners. Many studies conducted with middle and high school learners found that inquiry-based science activities had positive effects on learners' science achievements, cognitive development, laboratory skills, and understanding of scientific knowledge as a whole compared to learners taught using a traditional approach (Blanchard et al., 2010). Inquiry-based teaching is capable of shifting the focus of science education from memorization of facts and concepts to seeking answers to their own questions (Gibson & Chase, 2002).

In an effort to shift the emphasis from the transfer of knowledge in the classroom to development of scientific literacy (Liu, Liang & Liu, 2012), inquiry-based science teaching has become widely advocated in science education in many countries (Ramnarain & Schuster, 2014). Advocacy for this is based on the premise that inquiry is at the core of scientific literacy (Wong & Hodson, 2008). Scientific literacy is commonly viewed as the ability to make informed decisions on science- and technology-based issues.

2.4.1 Challenges in Implementing Inquiry

Research in science education has shown that the implementation of inquiry-based approaches has been a daily struggle for science teachers (Kim, Tan & Talaue, 2013). A significant number of studies have discussed the difficulties of science inquiry in terms of external factors (time constraints, curricular demands, learners' abilities and classroom structure) and internal factors (lack of knowledge, beliefs and attitudes) that hinder the use of the inquiry-based approach to teaching science (Chin, Goh, Chia, Lee & Soh, 1994; Yoon & Kim, 2010).

2.4.1.1 External Factors

These are factors that affect the implementation of inquiry-based instruction and have nothing much to do with the teacher. They can be viewed as technical and logistical concerns that teachers have that discourage them from implementing inquiry-based instruction. As highlighted by the following researchers, common impediments to implementing inquiry environments include: time constraints, students ability, school culture and parents expectations (Ramnarain & Schuster, 2014); perceived time constraints due to high-stakes testing (De Boer 2004); inappropriate curriculum materials (Beck, Czerniak & Lumpe, 2000); large numbers of learners, availability of resources, and the absence of trained laboratory assistance (Chin & Chia, 2006; Zion, Cohen & Amir, 2007); and unfamiliarity with how science is practised (De Boer, 2004). These are some of the reasons suggested for teachers' reluctance to adopt inquiry-based teaching.

Testing is being promoted worldwide as a means of ensuring that educational standards are maintained or improved and South Africa is not an exception. School leaving examinations are an integral aspect of education in South Africa. The learners' performance levels in these examinations are used by the Department of Education as a way to rank or evaluate schools, making them high-stakes summative assessments. A high-stakes test is any test prepared and marked externally, with the results being used to make important decisions about students, educators, schools, or districts, most commonly for the purpose of accountabilityty, scholarships and entry into tertiary education. In South Africa, schools and teachers are rated using their previous pass percentage and low performing schools (below an agreed percentage pass) are classified as 'underperforming schools'. These labels encourage teachers to adopt teaching practices that they perceive as the most effective for raising test scores rather than practices that focus on learner understanding (Pringle & Carrier, 2005; Shaver, Cuevas, Lee & Avalos, 2007).

Teacher-centred instructional approaches that focus on basic skill development are often reinforced at lower performing schools (Perrault, 2000). These schools will tend to resort to these approaches as they can be effective ways of raising the school's overall performance or learner test scores. This impacts the quality of science teaching (Saka, Southerland & Brooks, 2009; Settlage & Meadows, 2002; Shaver, Cuevas, Lee & Avalos, 2007) as many teachers were shaping their instruction to 'teach to the test' (Yore et al., 2008). DeBoer (2002) writes that standards-based education has created impediments to learner-centred teaching, and has reduced the autonomy and creativity of classroom teachers. Studies have shown that schools in areas with high levels of poverty are more likely to employ test preparation practices (Firestone, Monfils & Camilli, 2001). Teachers at lower performing schools and/or higher poverty schools were more likely to change their practices in response to high stakes testing because of the need to raise the test scores quickly in response to the increased scrutiny of the country, state officials or the public in general (Jones, Jones & Hargrove, 2003). This may suggest that there is a possible link between testing and classroom instruction. In a study by Ramnarain (2014) on the validity of questions, it was argued that examinations can positively reinforce the teaching of some concepts and the manner of the teaching, thus measurement specialism may exert control over instructions through tests.

2.4.1.2 Internal Factors

Internal factors are those that have much to do with the teacher. The teachers themselves have limitations or have within themselves internal contradictions regarding their own capabilities and beliefs about science teaching and inquiry-based teaching. Roehrig & Luft (2004) noted five main constraints that impacted the implementation of inquiry-based instruction: the teacher's understanding of the nature of science and scientific inquiry, content knowledge, pedagogical content knowledge, teaching beliefs, and concerns about management and learners. Many science teachers lack the necessary background knowledge and experience to implement inquiry-based learning. They thus lack confidence in implementing this type of teaching and do not routinely use inquiry-based instruction in their teaching. Common impediments to implementing inquiry environments include: inadequate preparation in science (Krajcik, Blumenfeld, Marx & Soloway, 2000), the low proficiency of teachers' content knowledge (Appleton, 2002) and limited classroom teaching experience (Luft, 2001). Recent research suggests that new secondary school science teachers may have a more difficult time implementing inquiry-based lessons than their experienced peers (Luft, 2001).

The majority of current teachers did not learn school science through inquiry and only a few have had experiences as adults learning science through inquiry. Lotter, Harwood, & Bonner, (2006) writes that many in-service teachers have had little or no experience as students in an inquiry-oriented classroom, thus, they are asked to implement a strategy that is an abstract construct to them.Teachers of all professions have the longest apprenticeship of teaching and learning; they observed teachers and learners during their time as learners and later on as teachers. This extensive exposure to a certain kind of teaching and learning method has led to individual conceptions of teaching in general and, later on, inquiry teaching. The teacher core conceptions were found to influence beliefs and practice (Lotter, Harwood & Bonner, 2007). Kim & Tan (2011) argue that besides the technical-rational aspects of practical work such as time, materials and laboratory condition, there are conflicts and negotiations that teachers encounter in their decision-making and engagement in inquiry-based instruction. The different ideas about inquiry exist not only 'in the heads' of science teachers, but are codified in authoritative documents, reinforced by textbooks, broadcast in the media and embodied in the practices of teachers who promote the use of inquiry as well as those who favour more traditional methods (Windschitl, 2004).

The most difficult challenge that exists in the mind is teachers' beliefs. Beliefs are personal constructs that are important to the individual, in this case, the teacher. Kim & Tan (2011) argue that teachers' beliefs have a strong influence on decision-making, actions and the interpretation of phenomena. Teacher beliefs guide instructional decisions, influence classroom management, and provide a lens through which to understand classroom events. The relationship between beliefs and practice is still the subject of debate; some researchers consider beliefs and practice as interactive, while others conclude that beliefs must change before practice can change. Research on teachers' beliefs has discussed various issues of science teaching, and has emphasized that teacher beliefs and actions are complexly interrelated; hence it is important to understand teachers' beliefs in order to improve their teaching in intended directions. However, we have little knowledge of teachers' beliefs about the goals and purposes of inquiry, of their knowledge of inquiry processes, or of their motivations for undertaking more complex and often more difficult-to-manage forms of instruction (Windschitl, 2002). Tsai (2002) provided evidence from his study that science teachers' practice of teaching is prominently derived from the congruency of their beliefs in teaching, learning and the nature of science. He coined a term to describe this coalition "nested epistemologies". He further alluded to the fact that if ever a conflict of their nested epistemologies exists, teachers are challenged in conducting practical work and transforming it into inquiry-based learning.

Teacher beliefs about practice are based in part on their practical teaching knowledge accumulated over a long period in the classroom. Van Driel, Beijaard and Verloop (2001) referred to this practical teaching knowledge as an integrated set of knowledge, conceptions, beliefs and values teachers develop in the context of the teaching situation. It is from this practical knowledge that teachers draw theories that guide their decisions in their classrooms. These "practical theories of teaching" are often difficult to change (Sanders & McCutcheon, 1986) because the process is slow and involves many steps. Teachers' practical theories often include beliefs about science, effective teaching and learning, and the ability of their learners.

Teachers' beliefs about their learners' abilities to learn also act as constraints to inquiry-based instruction. Roehrig & Luft (2004) described how lack of learner ability and motivation were cited as the most common constraints among teachers for not using inquiry instruction. The teacher who believes the learners are not capable is likely not to use inquiry as a method of teaching. Wallace & Kang (2004) found that the teachers' inquiry instruction was constrained by their beliefs that their learners were immature or incapable of completing laboratories without explicit teacher guidance.

Teachers' beliefs about what constitutes effective teaching and learning, influences their choice of instructional strategies (Lotter, Harwood & Bonner, 2007). These beliefs about how the school operates and how learners learn, act as constraints on teachers' instructional choices. An example of such beliefs is the belief that teachers need to transmit knowledge to learners so that they are better prepared for the examinations or standardized tests. Alternatively, teachers' beliefs around effective instruction can support inquiry-based teaching strategies (Crawford, 2000).Teachers' scientific epistemological views are often consistent with their instructional beliefs and practice (Tsai, 2006). Constructivist teachers hold views of learning and science that support inquiry-based teaching, while the empiricist teachers believe in teacher transmission of knowledge (Roehrig & Luft, 2004). A teacher that believes scientists use theories to understand observations, teach their learners to use theories to explain their findings, conversely a teacher who views science as an accumulation of facts and theories as truths, stress the completing of scientific procedures to gain the correct answers.

2.4.2 Studies on Teaching Science as Inquiry

This section presents the aspects of inquiry that has been addressed by research in science education. These aspects include the definition and understanding of the term inquiry, the benefits and challenges of inquiry, the extent to which textbooks include inquiry activities, the implementation of inquiry in science classroom, and different levels of inquiry and their use in the teaching and learning of science. Studies have compared inquiry-based instruction and more didactic classroom/laboratory methods (Berg, Bergendahl, Lundberg & Tibell, 2003; Cobern et al., 2010). Sadeh & Zion (2009) carried out an empirical study of two groups of high school biology learners. In the study, one group was exposed to an open-inquiry environment, while the other was taught in an inquiry environment where instructions and procedures were provided. They assessed the learners' performances according to four criteria: changes occurring during the inquiry, learning as a process, procedural understanding and affective points of view. They found that the open-inquiry group out-performed their peers on procedural understanding. In contrast, Klahr and Nigam (2004) compared the impact of direct instruction and discovery learning using a sample of 112 third and fourth grade learners. The learners in the discovery learning group received no teacher intervention beyond the suggestion of a learning goal. In the direct-instruction group the materials, goals, examples, explanations and pace were all teacher controlled. The researchers found that more learners in the direct-instruction group mastered the material than those in the discovery-learning group.

Several studies have reported on teacher inquiry practices (Crawford, 2000; Keys, Kang & Lyon, 2001). The majority of these studies focused on elementary science classrooms and pre-service teachers. Qablan & DeBaz (2015) carried out a study in a science methods course offered to pre-service science teachers at the college of education at the Hashemite University in Jordan. This research was aimed at facilitating the implementation of inquiry-based science teaching through the use of several classroom strategies. The elementary sources of data included informal participants' interviews, open-ended questionnares, student lesson plans and field notes from the methods course. Results indicated that those classroom strategies were useful for promoting pre-service science teachers' understanding and reinforcing their skills for teaching science through inquiry. Although the study was in a different country, at a university and with 80 pre-service science teachers in a science methods course, it has similarities to the current study since they both involve teacher development in inquiry-based teaching. The difference between the above-mentioned study and this study is that the facilitation of the implementation of inquiry-based science teaching is with three in-service teachers at their respective schools in South Africa.

An empirical study by Newman et al. (2004) identified teaching problems when pre-service teachers presented science as inquiry to their learners. These problems included the teachers' limited experience of teaching and learning through inquiry; the learners lack of exposure to learning science through inquiry; the variety of meanings that inquiry has; the inability to provide sufficient inquiry-based science learning experiences given the time constraints; and the conflict between modelling sciences as inquiry versus teaching inquiry. This, on its own, reveals the complexity of inquiry-based activities. Windschitl (2002) also alludes to the difficult issue of generating appropriate and investigable questions.

Minner, Levy and Century (2010) conducted a meta-analysis of inquiry where they analyzed 138 studies spanning the period 1984–2002. The studies examined instruction across a range of science disciplines and grades. They took place in different instructional contexts and employed a variety of instructional materials and curricula. The studies examined the impact of inquiry-based science instruction and a clear positive trend favouring inquiry-based instructional practices, particularly instruction that emphasized learners' active thinking and the ability to draw conclusions from data, was evident. Fifty-one percent of the 138 studies in the synthesis showed positive impacts on learners' content learning and retention from some level of inquiry-base science instruction. In 42 of the studies, more than half found that learners who experienced more inquiry did statistically significantly better than those who were exposed to less inquiry.

Bunterm et al. (2014) examined the effects of guided vs. structured inquiry on secondary learners' learning of science in Thailand. The dependent measures were content knowledge, processing skills, scientific attitudes and self-perceived stress. In comparison to the structured-inquiry condition learners in the guided-inquiry condition showed greater improvement in both science content knowledge and science processing skills. Learners in the guided-inquiry condition had to engage with the information more deeply.

Blanchard et al. (2010) carried out a study to compare the efficacy of guided inquiry-based instruction to more traditional, verification laboratory instruction in supporting learner performance on a standardized measure of knowledge of content, procedure and nature of science. The learners who participated in an inquiry-based laboratory unit showed significantly higher post-test scores; had higher scores, more growth and long-term retention at both the high school and middle levels, if their teacher had a stronger implementation of inquiry methods, regardless of the poverty level in the school. This suggests that guided inquiry can be an effective teaching approach to support the learning of science.

Chinn & Malhotra (2002) examined 468 inquiry tasks in nine textbooks written for upper elementary and middle school; none of the activities required learners to develop their own questions, only 2% of these activities required learners to select their own variables and there were few opportunities to think about controlling variables. This may suggest the critical need to integrate inquiry activities into the curriculum materials.

2.5 Pedagogical Orientation

To be successful in teaching, science teachers must not only have good content knowledge but also be able to translate this into appropriate teaching approaches (Ramnarain & Schuster, 2014). This way of representing and formulating the subject so that it is comprehensible to others (Shulman, 1986) is known as pedagogical content knowledge (PCK). Pedagogical orientation has been theorised as a component of pedagogical content knowledge (PCK) (Magnusson, Krajcik & Borko, 1999). Pedagogical orientation refers to a teacher's preferred approach in designing lessons and learning activities. Magnusson, Krajcik & Borko (1999:97) define orientations as teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level. They identified nine orientations to science teaching: process, academic rigour, didactic, conceptual change, activity driven, discovery, project-based, inquiry and guided inquiry.

A science teacher has to make a choice, either implicitly or explicitly, on the method of presenting, and explaining scientific concepts and principles. Scientific concepts and principles can either be presented directly to learners or learners can participate in exploring and finding the explanations themselves (Cobern et al., 2014). This is the most basic distinction between direct and inquiry modes of instruction. The former mode of instruction presents science as factual knowledge and the latter mode presents science as developed by a process of scientific inquiry. Each of the two modes is divided into two variants, thus providing four common teaching orientations. The four common teaching orientations are didactic direct, active direct, guided inquiry, and open inquiry. These are not to be seen as rigid compartments, but as a useful way of broadly characterizing instructional approaches found in practice. Studies have revealed the existence of orientations that are either in between the identified science teaching orientations in literature or have aspects of each (Friedrichsen & Dana, 2000).

Science teaching orientations are found to fall within a spectrum reflecting direct approaches at one end and inquiry approaches on the other end. These orientations reflect how a teacher would tend to design and structure instruction, especially learning activities. Few studies have been conducted that directly assess teachers' orientations to teaching science (Ramnarain, Nampota & Schuster, 2016; Ramnarain & Schuster, 2014).

Ramnarain & Schuster (2014) conducted their study in South Africa. The study used the POSTT-PS instrument to assess and compare the pedagogical orientations of in-service physical science teachers practising in township (disadvantaged) schools and suburban (advantaged) schools, and the results showed marked differences between the preferred teaching practices of the two groups of teachers. The results revealed that teachers in township schools tend to have a strong active direct teaching orientation, while teachers at suburban schools exhibited a guided inquiry orientation. The study adopted a sequential explanatory mixed method design and collected data from 44 township and 47 suburban schoolteachers. This study uses the same instrument to establish the pedagogical orientation of three physical sciences teachers. In addition to the POSTT-PS, semi-structured interviews and classroom observation were used.

2.6 Professional Development

The classroom is an important centre for teachers' professional development. Teachers' professional development is described as a process of embracing all activities that enhance professional career growth (Rogan & Grayson, 2003). These activities must address pedagogical weaknesses and professional issues that are relevant to the setting in which the professional development is delivered. The settings or contexts in which professional development occur must be able to support it (Harwell, 2003) for it to succeed. Besides the content and contextual factors affecting teacher professional development programmes, there are also methodological factors that affect the success of the programme (Villegas-Reimers, 2003). Hopkins, Harris, Singleton and Watts (2000) identified five training methods and their levels. Professional development should be based on curricula and instructional strategies that have a high probability of affecting learners' learning (Joyce & Showers, 2002). These authors concluded that in-class support such as coaching by a peer or an expert can have the highest of impact. In support of this idea, Hargreaves (2003) noted that the best way to spread new practices is on a peer-to-peer basis. The study is an in-class support of a peer acting as a critical friend to a teacher in inquiry-based teaching.

There is growing pressure to improve the quality of teachers and learning in most of the countries in the world. Findings from the studies on nations that perform well show that they put more emphasis on teacher selection, training and development allied to strict accountability (Ripley, 2013). International comparative studies are driving educational agendas that ensure school products that are well constructed and can keep up with change. It is therefore crucial that effective PD opportunities are afforded to most, if not all, teachers. The discussion above has shown that the PD of teachers is paramount if schools are to meet the aspirations of the stakeholders. Guskey (2002) noted that one constant finding in the research literature is the importance of PD in facilitating these improvements in education. Teacher PD is a term that was coined after the growing international acceptance of teaching as a profession (Villegas-Reimers, 2003). Prior to this, teaching was not regarded as a profession (Whitty, 2000), hence the use of the term teacher training instead of PD. PD is defined as a process whereby an individual acquires or enhances the skills, knowledge and/or attitudes for the purposes of improving their practice (Mitchell, 2013). The definition includes the word 'process' which suggests that it is not a single occurrence (Flint, Zisook & Fisher, 2011). The definition also includes the word individual, which could suggest that it is not a collective effort as it depends on the individual's disposition. In agreement, Avalos (2011) writes that, at the centre of any PD programme for teachers, is the understanding that PD is about teacher learning. Guskey (2002) defines PD as programmes and strategies designed to change teachers' beliefs and practices in order to improve the achievements of their learners. In contrast, Mitchell (2013) argues that PD cannot be defined in terms of conditions since the relevance of these factors depends upon the context in which it is implemented. One can argue that although the contexts are never the same, teacher development benefits the product, the learner. The programme on its own, not only caters to the needs of the teacher but their learners as well.

Teacher PD has become an important factor in educational reform initiatives in many countries because of the perceived link between teacher effectiveness and learner learning and success. Windschitl (2004) demonstrates that the success of any reform effort is dependent on the teachers. Research in the field of school effectiveness and school improvement has found that the quality of teaching is a critical factor in influencing learning (Chapman, Wynter , Burgess , & Mellis, 2014). Current research in the field of PD has tried to understand how the quality of teaching might be enhanced. Opfer and Pedder (2011) have identified PD as a promising mechanism for improving teaching and learning. They also state that a way to improve learners' learning is the provision of more effective professional learning for teachers. In support of this view, Mitchell (2013) views PD as the means of school improvement.

2.6.1 Models of Teacher Professional Development

Professional development comes in many forms, including teacher in-service training, conference attendance, department meetings, committee services, relevant university coursework, personal reflection, structured seminars, teacher conversations, co-teaching and professional study groups (Flint, Zisook & FIsher, 2011). In recent years many models have been proposed on how teacher PD can be conducted. Research literature has constantly mentioned two major approaches to PD, namely an embedded approach and an extracted approach (Hamilton, 2013). The two approaches have the presence of a mediator in common. A mediator facilitates the whole process of PD and can be either an external or an internal expert. When the mediation is from outside then it is considered an extracted approach, and when the mediation is carried out by a colleague, peer or from within the school it is an embedded approach. Extracted PD models constitute the privileging of an outsider's specialized knowledge (Flint, Zisook & Fisher, 2011). These PD models focus on transmitting predefined knowledge, which continues to be the dominant mode of PD in many countries (Schwille & Dembele, 2007). Professional conferences, or "train the trainer" models are the most common. In these types of professional development models, a school representative redelivers the material presented as an auditorium style meeting to colleagues upon returning to school. The teachers receive information from identified experts on strategies that they will then implement in their classroom. This results in crucial information being watered down or misrepresented (Fiske & Ladd, 2004). In contrast, embedded PD emphasises localised professional learning opportunities and is complex because it exists in nested systems of schooling, contexts and teaching (Opfer & Pedder, 2011). Embedded PD models take place in localized school contexts, largely because scholars consider the workplace central to effective and continued teacher development (Billet, 2001). In this case, teachers learn from one another within their own school contexts. There are many models of embedded PD and these include peer observation (Guskey, 2000), professional learning communities (Butler, Lauscher, Jarvis-Selinger & Beckingham, 2004), individual inquiry and peer mentoring (Joyce & Calhoun, 2010), teacher coaching (Tschannen-Moran & Tschannen-Moran, 2011), and teacher instructional rounds in which teachers study their schools' and peers' practices in order to improve teacher perfomances (City, 2011).

2.6.2 Characteristics of Effective Professional Development

The characteristics of effective PD have been proposed by renowned educationists and researchers. The nine common features are total time, extended support, authentic experiences, coherence with standards, development of lessons, modelling inquiry, reflection, transference, and content knowledge (Capps, Crawford & Constas, 2012). One important feature that has been identified to have an impact on the outcome of a PD programme is the duration of the program (Garet, Porter, Desimone, Birman & Yoon, 2001). The duration is measured both by time span and contact hours. Teacher learning activities of longer duration were associated with reported gains in teacher outcomes (Lauer, Christopher, Firpo-Triplett & Buchting, 2014). Teachers report that sustained and intensive PD has a greater effect on changing practice than short PD (Garet, Porter, Desimone, Birman & Yoon, 2001). This could be an issue of having enough time to go through and complete activities not necessarily the number of hours committed to a certain activity. There is still a gap on the issue of longer duration, for it is not yet established how long that time is. Guskey & Yoon (2009) proposed more than thirty contact hours, but there are still studies where noticeable changes were recorded with fewer hours (Kealey, Peterson, Gaul & Dinh, 2000; Doppelt et al., 2009). Desimone, Porter, Garet, Yoon and Birman (2002) argue that the duration of the programme is not important. In view of the two alternative views, Lauer, Christopher, Firpo-Triplett and Buchting (2014) concluded that the duration of a PD programme is determined by the objectives to be met and the complexity of the topic. Other research suggests that the amount of time involved in PD may not be as important as what is covered during that time. This may suggest that the quality of the activities or experiences that a teacher experiences is of considerable value.

The experiences of the participants are crucial in achieving the intended outcomes of any training or learning. In-service teachers' experiences with science both in the laboratory and in real-world settings have been shown to influence their use of inquiry in the classroom (Friedrichsen & Dana, 2005; Varelas, House & Wenzel, 2005). Teacher PD involves teacher learning and indirectly influences what happens in the classroom. Teachers report that PD that focuses on the academic subject matter (content), giving teachers opportunities for hands-on work (active learning), and is integrated into the daily life of the school (coherence), is more likely to enhance their knowledge and skills (Garet, Porter, Desimone, Birman & Yoon, 2001). This means that teachers who have the opportunity to undergo active learning and participate in authentic experiences, like conducting their own investigations in science, are likely to change their practice. According to Mayer, (2011) active learning involves attending to relevant material. The contents of the PD programme must involve problem-solving the task, individual exercises (Suldo et al., 2010), working with a scientist (Lotter, Harwood & Bonner, 2006; Lotter, Harwood & Bonner, 2007) and authentic inquiry (Lotter, Harwood & Bonner, 2007). It is predicted that teachers who experience authentic inquiry similar to what they are expected to implement in their future classrooms are able to translate their experiences and convey concepts to their learners (Dubner et al., 2001). A survey conducted by Pedder, James & MacBeath (2005) emphasized the importance teachers place on lesson-specific professional learning practices. In that study, teachers gave high scores for collaborative classroom-based PD activities, such as joint research and experimentation, team teaching and peer observation and feedback, but gave much lower scores. This may suggest that clear objectives must be identified before incorporating any activities in the PD programme and these objectives will have to be linked to the intended classroom practice so that it can be an authentic experience. This leads to yet another important characteristic - needs assessment.

Cekada (2010) describes needs assessment as a way to create training that is targeted to address the difference between preferred performance or knowledge and the employee's current performance or knowledge. This is very important in the design of a PD programme as it creates opportunities to identify the resources and type of training needed. In contrast, Lotter, Harwood & Bonner's (2006) results suggest that engaging teachers in identifying key issues in their own professional development is an ineffective strategy. The extended support given to teachers after the initial PD session gives teachers an opportunity to interact with the professional developer and receive feedback on innovations after experimenting in their classrooms (Garet, Porter, Desimone, Birman & Yoon, 2001). The support comes in the form of the professional developer physically visiting the teacher or classroom (or using technology) to answer questions, address concerns and receive feedback on progress. Capps, Crawford & Constas (2012) suggest that programs with a limited number of hours could make up for lack of time with increased follow-up support for teachers after they return to their schools. The writer is of the opinion that extended support can be integrated into every programme. Lee , Hart, Cuevas and Enders (2004) suggested extended support as an alternative approach; breaking the programme into a series of workshops throughout the year. Follow-up support is critical when implementing complex skills (Doppelt et al., 2009). Crawford (2000) argued that inquiry-based instruction is a complex activity, thus, in view of the discussion above, the PD programme for inquiry must include this important characteristic in its design.

The literature on teacher professional development has highlighted the importance of reflection in bringing about teacher change (Sellars, 2012). Reflection plays an important role in helping the teacher to reconceptualize their personal and professional knowledge. This philosophical perspective is based on Dewey's notion that people learn from experiences and reflection on those experiences. According to Beattie (2001), there is no intellectual growth without re-construction that is rethinking and re-examining. Reconstruction is the rebuilding of old concepts and experiences in order to deal with the demands of current teaching situations (Vazir, 2006).

2.6.3 Studies on Professional Development in Inquiry

The research literature on inquiry-based teaching and science teacher PD has been in existence for over a decade now. There have been reform efforts in science education and these efforts highlight the importance of inquiry instruction (Capps, Crawford & Constas, 2012). Teachers are now encouraged to place greater emphasis on inquiry-based instruction and less on direct instruction (National Research Council, 2000). However, recent research findings have shown that little has changed in the way science is taught in most schools. The teachers are still battling with teaching science through inquiry. In an effort to explain this state of affairs, Crawford (2007) argues that inquiry-based teaching is a complex and sophisticated way of teaching that requires significant PD. This poses a major challenge in the field of science education, especially in the area of assisting teachers in understanding how to implement inquiry-based instruction in their classroom. Capps, Crawford and Constas (2012) defined inquiry-based science PD as consisting of activities that support teachers in creating classroom environments in which learners learn science through inquiry.

Several studies have been conducted in this area, but more still needs to be done. It is not clear the amount of time that is needed for a successful PD programme with different researchers proposing different numbers of hours. In addition, many studies have recorded changes in teacher practice, but could not establish the permanency of the changes nor what could be done to achieve permanent changes. The studies have each made use of one or more of the nine common features of effective inquiry PD. The nine common features are: total time, extended support, authentic experiences, coherence with standards, development of lessons, modelling inquiry, reflection, transference, and content knowledge (Capps, Crawford & Constas, 2012). In 1998 Radford conducted a study that examined the impact of PD programmes on science teachers' and learners' content knowledge, processing skills and attitudes towards science. The programme ran for three years, which in terms of the definition, is considered a long programme. The participants had laboratory and fieldwork, thus the teachers had the opportunity to have authentic experiences. There were follow-ups and each teacher had a journal, which suggests the existence of extended support and reflection as well. This study included five of the features listed above and the findings demonstrated appropriate PD results in changes in teacher behaviour and improvements in learner attitude and achievement.

Jeanpierre, Oberhauser & Freeman (2005) carried out a study where scientists provided intense instruction in inquiry, with numerous opportunities for participants to carry out short inquiry-based research projects. They addressed all the stages of the full inquiry process and the findings show an increase in the number of teachers who practiced inquiry-based teaching in their classrooms. They identified the following characteristics of a PD programme as being critical in helping the teachers to use inquiry successfully in their classroom: deep science content and process knowledge with numerous opportunities for practice; the requirement that teachers' competence in a tangible and accessible way; and providers with high expectations for learning and capabilities to facilitate multifaceted inquiry experiences.

Lotter, Harwood & Bonner (2007) carried out a similar study with high school teachers, where the PD programme consisted of a two-week summer inquiry institute and research experience in university laboratories, as well as three academic year workshops where teachers reflected on the implementation of the lessons they had designed. Their professional development programme was designed on the tenets of high-quality PD, including being long-term, focused on subject matter knowledge as well as pedagogy, based on PD standards, and connected to teachers' real classroom context. Their data analysis revealed that a set of four conceptions influenced the type and amount of inquiry instruction in the teachers' classrooms: their conceptions of science, their learners, effective teaching practices and the purpose of education. Their research findings suggest that inquiry PD must not only teach inquiry knowledge but it must also assess and address teachers' core teaching conceptions. A number of core teaching conceptions were found to influence the participating teachers' beliefs and practice.

In a study by Akerson, Hanson and Cullen (2007) seven k-6 elementary teachers participated in a two-week summer workshop, and it was established that learning physics content knowledge through inquiry proved a challenge for the teachers. For many it was the first time they had personally experienced learning science using inquiry techniques. The teachers at times found the experience frustrating and constructing knowledge for themselves very difficult.

2.7 Empowerment Evaluation

Empowerment evaluation has provided a philosophy, a theoretical framework, and methods to address systematically concerns on self-assessment and accountability. It meets a specific evaluation need: to help programme participants evaluate themselves and their programme to improve practice and foster self-determination. Programme participants and community coalition members across the United States and abroad have used empowerment evaluation to improve their own lives.

Empowerment evaluation is the use of evaluation concepts, techniques and findings to foster improvement and self-determination (Fetterman, 2001a). It focuses on the empowering process and the outcomes. Empowerment evaluation is designed to help people help themselves and improve their programmes using a form of self-evaluation and reflection. The participants conduct their own evaluation and an outside evaluator often serves as the coach. The evaluator's role is that of a collaborator and facilitator rather than an expert counsellor. The evaluator learns about the participants through their culture, their worldview and their life struggles. The evaluator works with participants instead of advocating for them. The evaluator does not impose skills, interests or plans on the participants; rather the evaluator becomes the resource for the participants. What the evaluator does will depend on the particular place and people with whom he or she is working, rather than on the technologies that are predetermined to be applied in all situations. Interpersonal and evaluation skills are necessary, but how, where and with whom they are applied, cannot be automatically assumed. The evaluator does not and cannot empower anyone; people empower themselves, often with assistance and coaching. The evaluator must work towards making evaluations, a necessary and valuable activity. The evaluator and evaluation component is a means of empowerment. Evaluation is seen as a necessary process and an integral part of any advocacy or development work.

This process is fundamentally democratic. The assessment of the programme value and worth is not the endpoint of the evaluation, but part of an ongoing process of programme improvement. Empowerment evaluation acknowledges the non-static nature of merit and worth. There are inherent shifts within the programme and its environment that may invite reshaping of plans and strategies. Value assessment is also highly sensitive to the life cycle of the programme. The goals and outcomes are geared toward the appropriate developmental level of implementation. Empowerment evaluation and traditional external evaluation are not mutually exclusive. Empowerment evaluation process produces rich data that enables a more complete external examination.

Empowerment evaluation is not a panacea. The approach has been applied to a wide variety of programmes and diverse populations. It is a change process that has helped people from the corporate offices of Hewlett-Packard to townships in South Africa change their lives (Fetterman & Wandersman, 2005:1). Empowerment evaluation is designed to be constructive, helpful and useful at every stage of evaluation. Empowerment evaluation is personally rewarding, but it is also a time-consuming and labour-intensive process (Fetterman & Wandersman, 2005).

2.7.1 Origins of Empowerment Evaluation

Empowerment evaluation was introduced in a presidential address at the American Evaluation Association (Fetterman, 1994). Empowerment evaluation was born from a search for ways that evaluators and social scientists could give voice to the people they work with and bring their concerns to policy brokers. Collaboration, participation and empowerment helped to crystallize the concept of empowerment evaluation. Empowerment evaluation has its roots in community psychology and action anthropology. Community psychology focuses on people, organizations and communities working to establish control over their affairs. Action anthropology focuses on how anthropologists can facilitate the goals and objectives of self-determination. Empowerment evaluation also derives from collaborative and participatory evaluation. Collaborative and participatory evaluation coupled with action research laid the groundwork for empowerment evaluation. Empowerment evaluation has become an essential approach to evaluation that is consistent with the principles of community psychology (Suarez-Balcazar & Harper, 2003). Empowerment evaluation is rooted in empowerment theory (Zimmerman, 2000).

2.7.2 Empowerment Theory

The leading advocates of empowerment theory are Rappaport (1981) and Zimmerman. Zimmerman's work on empowerment theory provides a theoretical framework for empowerment evaluation. There are six dimensions to empowerment: it can be characterized as a philosophy, paradigm, process, partnership, performance or perception.

The philosophy of empowerment borrows from Rappaport's three guiding principles of an empowering philosophy. According to Rappaport (1981):

1. All people have existing strengths and capabilities as well as the capacity to become competent.
2. The failures of a person to display competences are not due to deficits within the person but rather to the failure of the social systems to provide or create opportunities for competences to be displayed or acquired.

3. In situations where existing capabilities need to be strengthened or new competencies need to be learned, they are best learned through experiences that lead people to make self-attributions about their capabilities to influence important life events.

Evaluation is conducted with the teacher, not on the teacher. There is no assumption that the teacher is incapable or devoid of an evaluative tradition of his or her own. There is no assumption that there is something inherently better about professionals and their methods; that somehow their methods, grounded in the western scientific tradition, are sounder, of greater ethical integrity or steeped in insight and wisdom.
The paradigm of empowerment evaluation entails mastery and optimization. Emphasis is placed on the development, enhancement and expansion of teachers' competencies and capabilities.

Evaluation is used as an enabling tool and process by the evaluator. The evaluator serves as a consultant helping the teacher to evaluate the work he or she deems necessary and important. In the early stages, the evaluator played a more significant role in helping in the needs assessment.

Empowerment evaluation is very much a partnership between the evaluator and the participants. This partnership is characterized by mutual respect and trust, reciprocity, open communication, shared responsibility, a shared appreciation for the cultural and socio-historical context within which the teachers and their organizations operate, and a common cultural style of communication and interaction. The balance of power intentionally rests with the participants. This, however, does not compromise the validity of the evaluation process. It only suggests that the evaluator does not single-handedly operationalize critical variables or define outcomes, processes or issues warranting investigation. In addition, an evaluator should never assume an authoritative position with respect to the interpretation of findings. Interpretations are solicited from the participant and synthesized with those of the evaluator. In empowerment evaluation, each perspective informs and enhances the other. The way a problem is defined or interpreted has a direct bearing on the solutions devised and the accepted measures of success. From the outset, it was clear that the participants had their own theories of human behaviour and the human condition (pedagogy and pedagogical practice). By allowing the participants to evaluate and articulate their problems and propose interventions, the evaluator is able to understand the participants' worldview and use it as a foundation for the creation of a variety of solutions.

The perception of empowerment entails a realistic view of the context in which the work occurs. The participants accurately appraise the reality of the mitigating conditions levied against them and the multitude of levels at which change must occur. They recognize that the process of change is incremental and therefore they do not make unrealistic or unfair assessments of success or failure in the process of empowerment. The evaluator's perspective is crucial to empowerment evaluation because it informs how problems are identified and defined, the paradigm that drives participants' efforts and the measures of both outcome and impact success.
It is critical that evaluators treat everyone with respect and not use their education and skills in an illicit fashion. Evaluators must not appear as people who check up on and discredit the work people do. There must be a mutual form of empowerment; we teach each other.

The role of the evaluator is critical to the effective performance of the evaluation work. The evaluator is on the same level as the participants and possesses no greater level of power. The evaluator is not giving anything to anyone but is engaged in a collaboration in which all parties bring equal, though perhaps different, forms of expertise to the table.

2.7.3 Philosophic and Political Groundwork for Empowerment Evaluation

Empowerment evaluation arose out of many evaluation traditions. It has much in common with collaborative and participatory forms of evaluation. Participatory evaluation emphasises participation and active engagement, which are features central to empowerment evaluation. Participatory evaluation is committed to local control and capacity building, which are some of the important values of empowerment evaluation. This does not suggest that there are no differences between empowerment evaluation and these closely aligned approaches. Alkin and Christie (2004) discussed distinguishing features between these approaches (participatory and empowerment evaluation) such as social justice ideals and process use. In addition, Christie (2003) highlighted the extensive involvement of stakeholders in all aspects of the evaluation, from inception to conclusion as opposed to “a role in limited aspects of the evaluation” in other forms of deliberative democratic evaluation.

Participatory evaluation laid much of the philosophical and political groundwork for empowerment evaluation. Participatory evaluation is applied social research wherein evaluators train key programme staff to work with them in the evaluation (O'Sullivan, 2004:24). Since participatory evaluation comes from the utilization framework, its goal is increased utilization through design, implementation, analysis and interpretation, as opposed to empowering those that have been oppressed, which is political or emancipatory in nature. Although empowerment evaluation is in itself participatory, not all participatory evaluations are empowering since they do not always focus on the transfer of skills and the building of evaluation capacity.

Collaborative approaches compel the evaluator to listen and respect participants' views, share evaluative endeavour and work together with other participants. Valuing community knowledge is a basic theme in empowerment evaluation, thus collaborative approaches to evaluation are regarded as shaping the tone and tenor of empowerment evaluation. In this scenario, the evaluator is not allowed to abrogate his fundamental responsibilities for the evaluation. Enhancing the participants' understanding of evaluation and acquisition of new skills, though a valuable outcome of the process, is unfortunately not an intended goal in collaborative evaluation as it is in empowerment evaluation. In other words, empowerment is a desirable side benefit of collaborative work but not required, as it is one of the primary goals of empowerment evaluation.

Another distinguishing feature of empowerment evaluation is its commitment to evidence-based strategies, including the development of systems that incorporate evidence-based strategies (Wandersman, Imm, Chinman & Kaftarian, 2000). This is one of the major principles that distinguish empowerment evaluation from the rest of the traditional evaluation methods.

2.7.4 The principles of Empowerment Evaluation

The principles of empowerment evaluation further distinguish it from participatory and collaborative evaluation. There are ten principles of empowerment evaluation, namely improvement, inclusion, accountability, organizational learning, evidence-based strategies, social justice, community ownership, community knowledge, democratic participation and capacity building.

2.7.4.1 Improvement

There is a fundamental assumption in the theory and practice of empowerment evaluation that the aim of the vast majority of programmes is to achieve positive results in the lives of those affected by the programme. Empowerment evaluation values improvement in people, programmes, organizations and communities. As the people improve their programmes, they, in turn, improve their lives. The work is not neutral or antiseptic. This is in contrast to a traditional evaluation, which values neutrality and objectivity and wants to examine programmes in their natural state in order to determine their effect without the influence of the evaluators. Empowerment evaluators roll up their sleeves and help people to help themselves. They help people improve their programmes through evaluation. Their commitment to improvement is manifested through capacity building. Empowerment evaluation is never conducted without the purpose of or prospect of improving the programme. Empowerment evaluators provide the necessary guidance, feedback and assistance to ensure participants achieve their objectives and realise the desired outcomes.

Some argue that, because evaluators are not neutral, evaluation findings are more likely to be biased, self-congratulatory or self-promoting (Stufflebeam, 2001). It can be argued that the integrity of an evaluation can be compromised in any evaluation approach. Participants working in an empowerment evaluation environment may actually be less likely to misrepresent data than participants who feel threatened by the evaluation. Some evaluators have found that because these values and participants are striving for programme improvement, they are actually more honest (Fetterman, 2001).

Empowerment evaluation has a bottom line orientation. This means that the empowerment evaluation like other evaluation approaches uses quantitative and qualitative data sources to evaluate the programme implementation process and short- and long-term outcomes. Empowerment evaluation adheres to the standards of evaluation (utility, feasibility, propriety and accuracy) set by the joint committee on education evaluation (Fetterman, 2001).

2.7.4.2 Community Ownership

Empowerment evaluators believe the community has a right to make decisions about actions that affect their lives. Evaluation is more likely to lead to improvement when the community is empowered to make decisions that direct the evaluation process right from the start. This commitment to community ownership distinguishes empowerment evaluation from traditional evaluation approaches and practical participatory evaluation where decision-making power regarding the purpose, design and use of evaluation results is held by the evaluator. In empowerment evaluation, there is no joint ownership and control of evaluation decision-making as in practical participatory evaluation. All evaluation roles are eventually assumed by participants. The more the participants control the conceptual direction and the actual implementation of the evaluation, the more they are likely to use the findings and recommendations. This is referred to as process use (Fetterman, 2001). The sense of ownership may vary based on the stage of development, the capacity and the history. Reinforced ownership gets stronger and deeper over time, especially when the participants learn that their judgment is valued and trusted. The process of doing the evaluation in a climate of trust and good faith only enhances a sense of ownership and pride. The ownership becomes stronger and more meaningful when the participants use their own evaluative findings to improve their practice. A major role of empowerment evaluators is to promote a developmental approach to capacity building and community ownership that enables participants to perform empowerment evaluation. Empowerment evaluators have influence in the process as consultants, facilitators, coaches, teachers and critical friends, but they do not have decision-making power. The participants have the power to choose whether to incorporate this influence into their decision-making. Community ownership does not mean the empowerment evaluator does not state their opinions strongly, but their voice is just one of the voices on the table. The participants will then decide what to do and not to do with the opinions expressed by the empowerment evaluators. The empowerment evaluator does not relinquish their authority as experts in the area of evaluation, but this authority does not extend to the point of usurping the decision-making authority of the participants. Empowerment evaluation embraces the value of community ownership because putting evaluation in the hands of participants is thought to foster self-determination and responsibility.

2.7.4.3 Inclusion

Inclusion means inviting as many stakeholders to the table as is feasible or reasonable and making a concerted effort to encourage participation. Inclusion is about bringing all pertinent groups together. Participants have a tremendous amount to offer. They know their own conditions. They can ground the administrators in their reality, forcing them to reshape programme implementation. Inclusion does not on the surface appear to be an efficient mechanism, the more people invited to the table the more time required for scheduling and consensus building. Leaders may seem busy but must be encouraged to participate, as the failure to include all the critical players results in missed opportunities. All of the key players bring valuable insights and interests to the table. Multicultural contributions are a plus, not a minus. They also ensure an authentic or meaningful consensus. This is needed for any plan of action to move forward. Not being inclusive can be counterproductive to empowerment evaluation and often results in poor communication, undermining behaviour and creating a lack of staff. Empowerment evaluators find that better solutions emerge as a result of inclusive consultation with participants and their leaders. Inclusion is thought to be a better way of facilitating ownership of the evaluation process and the use of evaluation results by all stakeholders to guide practice and programme improvement. The principle of inclusion is often confused with democratic participation.

2.7.4.4 Democratic Participation

The principle of democratic participation is viewed as critical for establishing stakeholder buy-in. Democratic participation speaks to how the participants will interact and make decisions. It ensures that everyone has a vote in the process or a meaningful role in decision-making. Everybody, regardless of his or her level, has an equal voice. Democratic participation is a means of ensuring equality and fairness and a tool to encourage as many insights and suggestions about how to improve programmes as possible. Democratic participation underscores the importance of deliberation and authentic collaboration as a critical process for maximizing the use of the skills and knowledge in the community. It emphasizes that fairness and due process are fundamental parts of the empowerment evaluation process. Empowerment evaluators should strive to make evaluation plans and methods clear and straightforward. Clarity and openness increase trust, which is critical to participants being willing to share negative findings and to modify programmes based on evaluation results. Participation has been shown to increase feelings of control (Wandersman & Florin, 2000) and should increase the ownership and use of evaluation tools and findings.

2.7.4.5 Social Justice

Social justice is a fundamental principle guiding empowerment evaluation (Fetterman, 2001:142). Empowerment evaluators believe in and have a commitment to social justice (Dalton, Elias & Wandersman, 2001). The empowerment evaluators strive to ameliorate basic social inequalities by helping people use evaluation to improve their programmes so that communities are positively impacted in the process. The programme may be designed to improve the education of disenfranchised or minority populations. The aim of empowerment evaluation is to make a difference for the larger social good. Empowerment evaluation is well suited for people and programmes that are interested in improving their performance. Empowerment evaluators believe all programmes designed to help the people and communities at any level ultimately contribute to the larger goal of social justice. A commitment to social justice naturally flows from the commitment of empowerment evaluation to help individuals develop their capacity for intelligent judgement and action by supplying them with the methods, tools, techniques and training to improve their programmes. Although there is a bias toward traditionally disenfranchised populations, an empowerment evaluator might work with any other type of communities in an effort to ensure equality of opportunity, due process and racial or ethnic diversity. Evaluative data may suggest eliminating a social service programme because it is not cost effective. However, the social justice agenda might override that decision or force an organization to find ways of subsidizing that activity. The social justice principle is instructive at many levels; it influences how we treat people. Respect becomes paramount. The pride of an individual is fiercely protected and the struggle he or she is engaged in is honored.

2.7.4.6 Community Knowledge

In empowerment evaluation, community knowledge and wisdom are valued and promoted. It embraces local community knowledge and posits that people know their own problems and are in a good position to generate their own solutions. This respect for community knowledge often leads the evaluator to recognise tacit knowledge, making this knowledge explicit so that it can be shared and synthesized into new knowledge. Empowerment evaluation recognizes the limitations of externally exported solutions derived from various contexts. However, empowerment evaluation, in contrast to some other evaluation approaches, embraces evidence-based strategies to enhance local thinking and practice. Local community members have invaluable knowledge and information about their community and its programmes. Respecting their knowledge and valuing it makes sense from a pragmatic perspective. Local communities develop their own community knowledge within the organization and if this knowledge is mobilized it can be an extraordinary catalyst for change in an organization (McDermott, 2001).

2.7.4.7 Evidence-based Strategies

Empowerment evaluation values the role of science and evidence-based strategies. Just as empowerment evaluation respects the knowledge of the community, it also respects the knowledge base of the scholars and practitioners who have provided empirical information about what works in particular areas. This allows the evaluator to build from existing literature or practice and avoid reinventing the wheel. However, evidence-based strategies must not be adopted blindly and without regard for the local context (Fetterman, 1998). In most cases, adaptations are necessary before the practices can be useful in a community setting. Empowerment evaluators must combine evidence-based knowledge and the community knowledge of context and participants when planning and implementing interventions. The value placed on community knowledge is an essential counterbalance to the respect for evidence-based, best practices. Evidence-based strategies offer programmes, strategies or interventions that have worked in similar communities and populations. In essence, they offer a useful option that has a track record and external credibility. Evidence-based strategies should not be considered silver bullets, but useful ideas and models potentially adaptable to the local context and environment.

2.7.4.8 Capacity Building

Capacity building can be defined as individual changes in thinking and behaviour and organizational changes in procedures and culture that result from the learning that occurs during the evaluation process (Fetterman & Wandersman, 2005). Capacity building is one of the most identifiable features of empowerment evaluation (Fetterman, 2001). The participants learn how to conduct their own evaluations. In the process of internalising and institutionalising evaluation, they should be making evaluation a part of planning and management as well. Empowerment evaluators believe that when individuals learn the basic skills and steps involved in conducting programme evaluations, they are in a position to shape their lives and the lives of those affected by the programme. Empowerment evaluation is designed to enhance the individual's capacity to conduct evaluations and to improve programme planning and implementation simultaneously. Empowerment evaluation incorporates user-friendly tools and concepts to increase the probability of their use after the support has been withdrawn.

2.7.4.9 Organisational Learning

Organizational learning has been defined as the process of acquiring, applying and mastering new tools and methods to improve processes (Schneiderman, 2003). Empowerment evaluation helps to create a community of learners (Fetterman, 2001) where feedback is used to make corrective and adaptive changes in organizational behaviour. Empowerment evaluation encourages informed decisions (data-driven decisions). The data is derived from participants' self-reflection and analysis. Empowerment evaluators encourage participants to evaluate their performance continually. Empowerment evaluators have a responsibility to help make the environment conducive to organizational learning. Empowerment evaluators help to develop both a climate and structures for generating reflective practitioners.
This leads to a focus on systems issues and system thinking rather than short-term solutions and quick fixes.

2.7.4.10 Accountability

Empowerment evaluation is about accountability (Fetterman, 2001:118) and focus is directed towards the final product. It is useful for both external and internal accountability, with the latter being its strength. It uses internal accountability to achieve both internal goals and external requirements or outcomes. External accountability is a fundamental reality in empowerment evaluation since the evaluations are conducted within the context of external requirements and demands. It provides an innovative vehicle for helping individuals to be accountable to the public and themselves by generating process- and outcome-oriented data. The data should hold the individuals or organizations accountable for their activities and plans. Empowerment evaluation places a high priority on process accountability. This principle, in combination with other empowerment evaluation principles, creates a self-driven, rather than other-driven concept of accountability. Accountability is a mutual and interactive responsibility of the funder, researcher and practitioner. The stakeholders are intertwined in a triple helix of accountability to one another to obtain results (Wandersman, 2003). The stakeholders must understand how and why the programme outcomes were or were not produced. If the outcomes were positive, they can pinpoint some of the processes that led to programme success.

Conversely, if the outcomes were less than expected, they can identify the factors that interfered with success. Empowerment evaluation is committed to learning from process and implementation and its practitioners need to know if the intervention worked. Empowerment evaluation is focused on both formative and summative forms of evaluation accountability. The more work put into formative evaluation, the more likely the programmes to achieve success at the summative phase. The getting to goals system (Wandersman, Imm, Chinman & Kaftarian, 2000) is an example of a tool that helps promote result-based and process accountability.

2.8 Chapter Summary

Literature on inquiry-based teaching, pedagogical orientation, professional development and empowerment evaluation was presented. In addition, the chapter reflected on the theoretical and conceptual framework of the study. Learning was viewed from a social constructivist perspective that postulates that learners do not come into the science classrooms with empty heads, but bring with them their views that have developed as a result of their experiences. The teaching of science must acknowledge the existence of this knowledge that may either impede or facilitate the learning of new concepts. Learners must be given opportunities to construct knowledge and teachers must be equipped to facilitate knowledge construction as opposed to content acquisition. The research has demonstrated that teachers have a preferred way of presenting science that can either support or be in conflict with the teaching of science as inquiry. This preference is termed the pedagogical orientation of the teacher and influences the implementation of reform-based teaching of science. The literature has confirmed the need for professional development in inquiry-based teaching. The characteristics of effective professional development were presented with time being one of the important factors in both the implementation of inquiry-based teaching and in professional development. Teachers require enough time to learn how to implement inquiry-based teaching and to implement inquiry-based teaching of science in their classrooms. Empowerment evaluation can be used for the science education professional's development through facilitating individual evaluation as a means to foster self-determination. The challenges experienced by the science teachers in implementing inquiry-based teaching are caused either by internal or external factors, with the majority of them being external. Some of the external factors were the unavailability of resources (time, human and material), lack of administrative and collegial support, pressure of summative assessments, and class size.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter provides an outline of the research design and explains the methodology employed by the study. It accounts for the choice of methods, selection of participants and the manner in which data was collected and analyzed. This study employs a mixed method approach to answer the research question: How can an empowerment evaluation approach influence and shift the practice of Physical Sciences teachers towards an inquiry-based pedagogy?

The following objectives are linked to the research question:

1. To establish the current pedagogical practices of South African Physical Sciences teachers in inquiry-based teaching.

2. To determine the challenges experienced by Physical Sciences teachers in implementing an inquiry-based teaching approach.

3. To examine shifts in the pedagogical practices of Physical Sciences teachers in inquiry-based teaching due to an empowerment evaluation approach.

3.2 Research Paradigm

It is important that a valid methodology is framed within an acceptable educational research paradigm. A paradigm is a matrix of beliefs and perceptions (Heppner & Heppner, 2003) - mind-sets of age. A research paradigm is, therefore, a set of interrelated assumptions about the social world. Different paradigms offer different views on the nature of knowledge and how we come to that knowledge. There is often more than one paradigm that can frame a single study and these paradigms can often conflict with one another. It is important to establish a single paradigm from the competing paradigms as the paradigm chosen anchors the study in the appropriate ontological and epistemological perspective. According to Heppner &

Heppner (2003), there are five main research paradigms and these paradigms are positivism, post-positivism, interpretivism, participatory and pragmatism.
A summary of these paradigms is given below in Table 3.1. The research paradigm selected for this study was pragmatism. In this regard, it is useful to consider why pragmatism was considered in this study. The justification of the choice of pragmatism as a paradigm in this study warrants a brief discussion of the common paradigms used in social science and educational research.

Positivism is a result of the quest for objective knowledge. It is underpinned by objectivist or realist ontology. This paradigm involves the formulation of hypotheses, the collection of clinical observations, as well as a presentation of findings using statistics (O'Donoghue, 2007). It uses statistical logic, measurement, correlation and even verification to explain how and why things happen. Positivism assumes that things are as they seem to be and exist in a manner that is independent of the perceiver (Humphrey, 2013). This view provides a rationalistic view of knowledge with a single reality (Pontoretto, 2005). However, human beings have a complex nature and social phenomena have an intangible and elusive quality, unlike the regularity and order of the physical world (Cohen et al, 2011).

Post-positivism is a slight deviation from the ontological and epistemological position of positivism. It refers to a change of thinking from a traditional positivist's view of absolute truth to a view that there are multiple realities when conducting research on human interactions (O'leary, 2004). There is a component of probability to be considered; instead of findings being true, findings are probably true. The post-positivist perspective uses deductive reasoning based on existing theories (Creswell, 2009).

Interpretivism focuses on interpretation and observation as ways of gaining an understanding of the social world (Ritchie & Lewis et al, 2013). Interpretivists hold that there is an ontological gap between human beings and their social worlds (Cohen et al, 2011). In interpretivism research is value-bound because what is being researched is a function of a particular set of individuals and circumstances at a particular time (Saunders & Tosey, 2012). This suggests knowledge is specific to the situation being investigated (O'Donoghue, 2007). Thus, in the current study, it is useful to consider teachers' pedagogical practices within the context in which they operate. In seeking understanding, Interpretivists do not normally begin with a theory; rather they inductively develop patterns of meaning (Creswell, 2003). The interpretivist's paradigm relates to the study of social phenomena in the natural environment in which the phenomenon occurs (Saunders & Tosey, 2012).

Participatory is based on the ontological assumption that reality is co-created by the mind and the given context. It represents a further shift from positivism than post-positivism does. It is founded on historical realism. It says; what is seen as the truth has been shaped by social, political, cultural, economic, ethnic and gender values. The epistemology is based on the interactions between the researcher and the researched, and subjectivity. The values of the researcher are considered to influence the findings and the methodology is based on dialogue.

Pragmatism focuses on interpretive and positivist epistemologies based on the criteria of applicability and fitness in relation to the purpose (Johnson & Onwuegbuzie, 2004). The belief is that the truth is what works and what is useful. The paradigm utilizes tools from both the interpretivist and positivist paradigms such as interviews, observations and experiments. Pragmatists consider that a single viewpoint cannot give the entire picture (Saunders & Tosey, 2012). It's not just a collection of a variety of tools, but that which results in reliable, credible and relevant data being collected. Pragmatism serves in bridging the divide between positivism and interpretivism (Krauss, 2005). It offers multiple perceptions about a single reality (Healy & Perry, 2000) making mixed methods research an inclusive, pluralistic and electric approach.

Mixed method research has been dominated by two philosophical traditions: positivism and interpretivism (Brannen, 2005). The quantitative aspects of the study are located within the positivist tradition while the qualitative aspects are located within an interpretivist tradition. Mixed method research uses a method and philosophy that attempts to fit together insights provided by both qualitative and quantitative research (Johnson & Onwuegbuzie, 2004). This means the mode of inquiry is both inductive and deductive.

Table 3.1: Elements of Research Paradigms

PARADIGM (Matrix of beliefs)	**Positivism**	**Post-positivism**	**Interpretivism (Constructivism)**	**Participatory (Collaboration)**	**Pragmatism (Truth is what works and is useful)**
ONTOLOGY (How reality is viewed)	**Naïve reality** (Apprehend 'real' reality)	**Critical reality** (Apprehend probabilistically)	**Relativism** (Specifically constructed meaning making)	**Subjective–objective** (Co-created by the mind and the given context)	**Reality not absolute** (Many philosophical views all contribute to reality)
EPISTEMOLOGY (Relationship with 'true' knowledge)	**Objectivist** (True findings)	**Modified objectivist** (Findings might probably true)	**Transactionally created findings** (Subjective experiences)	**Critical subjectivity** (Experiential and co-created findings)	Both **Transactionally created findings** and **modified objectivity**
METHODOLOGY (Likely methods of gaining knowledge)	**Experimental** (Quantitative methods)	**Modified experimenter** (quantitative and perhaps qualitative methods)	**Dialectic** (Hermeneutic)	**Action research** (Collaborative inquiry)	**Mixed methods research** (Qualitative and quantitative strands)

Adapted from: Heppner, P.P. and Heppner, M.J. (2003: 133-135). Writing and publishing your thesis, dissertation, and research. *A guide for learners in the helping professions.* Thomson Learning, Toronto, Canada: Brook

3.3 Research Design

There are three main research designs currently discussed in the literature, namely quantitative, qualitative and mixed methods (Creswell, 2009). The quantitative approach does have positivistic assumptions as they emerged from the natural sciences while the qualitative approach emerged from the social sciences. The latter (mixed methods) draws from the strength of each of the two (quantitative and qualitative) and is not there to polarise their positions nor foster the belief that the only available option is the choice between the two extremes. As argued by Johnson & Onwuegbuzie (2004) the goal of mixed methods is not to replace either qualitative or quantitative designs but to minimize their weaknesses. A mixed methods research design was adopted for this research study.

3.3.1 Mixed Methods Design

Mixed methods research is described by Johnson & Onwuegbuzie (2004:17) as "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language in a single study''. Mixed methods utilises the strength of both qualitative and quantitative research (Creswell, 2009). The combination of the two approaches is viewed as achieving more when addressing complex problems in social science research, than a single approach could have done. Creswell (2009) identified four aspects that influence the design of procedures for mixed methods study. The four aspects are timing, weighting, mixing and theorising.

Timing A decision has to be taken on whether qualitative and quantitative data collection will be in phases (sequentially) or at the same time (concurrently). When collected in phases, it is important to know the order of the data collection, either qualitative followed by quantitative or vice versa. For this study both qualitative and quantitative data were collected concurrently, for example the POSTT-PS instrument collected quantitative and qualitative data simutaneously.

Weighting An assumption is made that when data is collected concurrently then the qualitative and quantitative approaches have the same weighting. The sequential design presupposes a difference in the priority given to the two approaches. This can be determined by whether the inductive or deductive approach of analysing data is used. In some cases the researcher chooses to use one form of data in a supportive role. For this study data was collected concurrently and the qualitative and quantitative approaches were given equal weighting.

Mixing The mixing of two types of data might occur at several stages; the data collection, data analysis, interpretation or all three stages. In one study the qualitative data and the quantitative data can be collected concurrently and merged or integrated. In another study the two types of data may be collected with one considered as primary data and the other used in the supporting role. With the latter, data of one type is collected and analysed, then another type is collected. For this study qualitative and quantitative data were collected concurrently and both were merged for analysis and interpretation.

Theorising Researchers bring theories and frameworks to their enquiries that guide the entire design. These work as lenses that shape the types of questions asked, who participates in the study, how data are collected, and the conclusions made from the study.

3.4 Context of Study

The study was carried out in the eastern part of the Gauteng province. Primary and secondary school education in South Africa is governed by the Department of Basic Education (DBE). The DBE officially groups grades into two bands called General Education and Training (GET), which covers grades R - 9 and Further Education and Training (FET), which covers grades 10 - 12. Physical Sciences, a combination of physics and chemistry, is one of the school subjects offered at FET. The teachers who participated in this study were teaching Physical Sciences at three separate schools in the townships. In South Africa, the term township usually refers to the often-underdeveloped urban residential area, previously (during apartheid) reserved for non-white residents (blacks, coloureds and Indians). Townships are usually built on the periphery of towns and cities. A township school then becomes one built in that area for the purposes of servicing the non-white community. The schools were formerly disadvantaged schools and the majority of their learners are from the low-income families who reside in the township. Ramnarain & Schuster (2014) describe the parents as generally poorly educated and being employed in low-paying jobs. The schools therefore charge low fees and, in some cases, are classified as no-fee schools. These schools receive much of their resources and funding solely from the government. The selected teachers were teaching an average of forty learners per class. Two of the schools had laboratories, while the third was fairly new and did not have a laboratory. In the third school, the teacher was using the classroom as a laboratory.

3.5 Research Methodology

The triangulation mixed methods design was used for this study: both qualitative and quantitative data were collected, merged and the result used to understand the research problem (Creswell, 2002). Quantitative data was collected using two instruments: POSTT-PS and the Electronic Quality of Inquiry Protocol (EQUIP) observation tool. The quantitative data was merged with the qualitative data from the case study of the three teachers. A case study is the preferred approach when (a) how or why questions are being posed, (b) the investigator has little control over events, and (c) the focus is on a contemporary phenomenon within a real-life context. As mentioned above the research question wants to establish how an empowerment evaluation approach can influence and shift the practice of Physical Sciences teachers towards an inquiry-based pedagogy. The question seeks to explain a social phenomenon; this requires an extensive and in-depth description of that social phenomenon. A case study is a qualitative approach in which the investigator explores a bounded system over time, through detailed, in-depth data collection involving multiple sources of information (Merriam, 2009). The case study approach was, therefore, the most suitable method to use to help answer the research question.

The second reason for choosing the case study approach was the little control that the researcher had on the events. There are many variables of interest, thus leaving the researcher without much control of the events, hence the need for a method that allows the researcher to retain the holistic and meaningful characteristics of real-life events (Yin, 2009). Pedagogical practice is a complex phenomenon that calls for the researcher to capture various nuances, patterns, and other more latent elements. Only case studies can achieve this because they use a versatile, qualitative approach to research, which enables the researcher to understand a complex issue and brings with it familiarity to the case that no other research approach can do (Wilson, 2013). A case study, like any other form of qualitative research, searches for meaning and understanding (Merriam, 2009).

The third reason for choosing a case study is the phenomenon pedagogical practices in inquiry-based teaching is a contemporary phenomenon. A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context (Yin, 2003). In order to understand the complex relationship between empowerment evaluation as a form of professional development and the shifts in inquiry-based science teaching practices, there is a need for a together with the factors that mediate change in teacher practice.

This study exhibits four key characteristics of case studies: a bounded system, a case, holistic nature and multiple sources of data. A case study approach is not defined, as are others, by the focus of study, but by the unit of study. The unit of study - the case - characterizes a case study. A case is a single entity; it could be a person, a group, an institution, a community or a policy (Creswell, 2007). In this study, each teacher constituted a case and, by focusing on individuals, the researcher aimed to uncover the interaction of significant factors characteristic of this individual. The term holistic nature suggests studying every dimension of each participant. A case study does not actually use data gathering as suggested by some researchers (Merriam, 2009), but a methodological approach that incorporates a number of data gathering measures (Merriam, 2001; Yin, 1998). A case study does not use any particular method of data collection but does use some techniques more than others do. Hagan (2002) identified the following as data-gathering methods for case studies; life histories, documents, oral histories, in-depth interviews and participant observation.

The issue of face value credibility makes case studies attractive when searching for understanding rather than a mere explanation. Face validity, as the name suggests, is a measure of how representative a research project is at face value, and whether it appears to be a good project. Case studies can be designed as single or multiple cases. A multiple case study contains more than a single case (Yin, 2003). This study uses a multiple-case design.

Although the case study method was chosen for the study, it is important to appreciate that it also has its own challenges. The main critics of case studies cite the limitations in validity especially construct validity. Construct validity attempts to measure how accurately an experiment represents what it is trying to measure. They cite the potential subjectivity of the researcher. To minimize the effects of these limitations, Yin (2003) recommended establishing a chain of evidence, the use of multiple sources of evidence, and constant and consistent member checks. The reliability and generalizability of case studies are also questioned since the study of a few cases is seen as not being representative of the entire population. It may be argued that not all investigations are conducted for the purposes of generalization. In the context of this research, the intention is not to generalize for a large population, but to explore the concept of empowerment evaluation as a method of professional development. In terms of reliability, each case is unique and a subsequent researcher may not come to the same conclusion. This study focuses on three participants; each participant constitutes an individual case.

3.5.1 Research Sample

Three Physical Sciences teachers participated in the study. They were selected from township schools in one of the districts in the Gauteng province. All three teachers have vast experience in the teaching and learning of physical science making them information-rich cases. They were selected from schools near the researcher's workplace, thus enabling the researcher ease of access. The selection of a case is not based on its representativeness but its uniqueness (Mcmillan & Schumacher, 2001). Since pedagogical practice is unique and personal to each teacher

(Loughran, Berry & Mulhall, 2006), it was important to examine a small number of participants carefully and in detail. Three teachers were deemed to be suitable for this study given the extensive data sets which would come from the various interviews and observations. Teaching Physical Sciences with an eagerness to shift practice towards inquiry-based teaching was the criteria used to further ascertain the inclusion of the participant in the study. The three were teaching Physical Sciences at that particular time, were easily accessible to the researcher and eager to try inquiry-based teaching. This is termed purposive and convenience sampling. Purposive sampling is based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned" (Merriam, 1998: 61).

All three teachers were teaching in secondary schools, grades 8 - 12 as part of their teaching load, but each of them had classes allocated for Physical Sciences grades 10-12. All three teachers had more than five years' teaching experience. A summary table (Table 3.2) of the participants' background information is given below as an introduction to each participant. The data for the summary table was collected from the first interview with the participants. Note that each of the participants was assigned a pseudonym to protect his/her identity as required by the university's ethics regulations. All three were formally invited to the study by way of an invitation letter, which also explained the research. They all signed the letter of consent to participate in the study.

Mr Charles was the most experienced of them all. He holds a Bachelor of Education degree (Chemistry) and an Advanced Certificate in Education (ACE) - Physical Sciences. ACE is a qualification for in-service teachers who hold at least a three-year teacher's qualification that was offered in South Africa in response to the demand for qualified Physical Sciences teachers by the Department of Education.
In addressing the shortage of qualified Physical Sciences teachers, the government of South Africa gave a firm undertaking to train more teachers and provide additional training to those already in service. The ACE was envisaged as a professional qualification to enable teachers to develop their competences or to change their career path and adopt new teacher roles (Departent of Education, 2000). This was a

form of professional development for Mr Charles, even though it was not focused on inquiry-based teaching. He was the head of the department (HOD) of science at one of the schools at the time of the study. Being the head of the department meant he was part of the school management team and, having completed ACE, could have meant he was exposed to inquiry-based teaching. He had vast experience in teaching school science and teaching Physical Sciences in particular.

Mr Moloku has a Diploma in Education from a college of education, a Bachelor of Education degree (Physics) and a Masters in Science and Mathematics Education. He is highly qualified and has taught Physical Sciences for many years. He has sixteen years of science teaching experience and has taught Physical Sciences for the past eleven years.

Mr Kapok is the youngest of the three and holds a Bachelor of Education degree (Natural Science). He has taught Physical Sciences for five years. Mr Kapok had not received any in-service training on inquiry-based teaching.

Table 3.2: Summary of each participant background information

Background Questions	Mr Kapok	Mr Moloku	Mr Charles
Experience in teaching Physical Sciences	5 yrs.	11 yrs.	12 yrs.
Current school type	Public, grades 8-12	Public, grades 8-12	Public, grades 8-12
Current employment position	Teacher	Teacher	Head of the department of science (a member of the school management team responsible for the science department in the school)
Grades/classes currently being taught	10-12	11-12	10-12
Teacher training	Bachelor of Science Education (Natural Sciences)	Diploma in Education, Bachelor of Science Education, Masters of Science Education	Diploma in Education, Bachelor of Science Education, postgraduate ACE Science Education
In-service Professional development in inquiry-based teaching	None	ACE	ACE

3.5.2 Data Collection

The research design and the research question, in particular, determine the data collection instruments (Creswell, 2009). Data are nothing more than ordinary bits and pieces of information (Merriam, 1998). Whether information qualifies as data or not depends solely on the interest and perspective of the researcher. Qualitative data are descriptive (conveyed through words) as opposed to quantitative data, which are numeric. To get descriptive data quotations from interviews are gathered, observed behaviour is described and sections are extracted from documents. Table 3.3 below shows the three phases of data collection in this study in the form of a planning matrix.

Phase 1 (Baseline): This involved the collection of quantitative data from the EQUIP classroom observation tool and the administering of a POSTT-PS instrument. Qualitative data was obtained by conducting a follow-up to the POSTT-PS interview, semi-structured interviews and field notes from a classroom observation of each participant teaching Physical Sciences. The data gathered at this stage was used to establish the individual teacher's orientation to science teaching, current pedagogical practice and challenges faced when implementing inquiry-based teaching. Orientations refer to a teacher's preferred approach in designing lessons and learning activities and implementing them in class. This completes the first step (stocktaking) of the empowerment evaluation programme. Once the teacher's profile had been established, the teacher and the researcher commenced with the planning phase.

Phase 2 (Planning): This phase was divided into three (audio-recorded) meetings in order to set goals and strategies, and identify the yardsticks for measuring success. It involved the collection of data through meetings with the teacher to set goals, come up with strategies to meet the set goals and listing the indicators of achieved goals. Qualitative data from the minutes of the meetings were collected. This completed the second and third step (goal setting and developing strategies) of the empowerment evaluation programme (Fetterman, 1994).

Phase 3 (Implementation) The teacher was then observed and video recorded while implementing the strategies identified in the meeting in phase 2. The classroom observation was followed by stimulated recall informal discussion of the proceedings of the lesson and the teacher was expected to reflect on what had transpired in the lesson and evaluate the teaching and learning process. After every observed lesson a post-lesson interview was scheduled to assess the progress, and strategies were reviewed to determine their effectiveness and appropriateness. All the interviews were audio-recorded and fully transcribed. At the end of the intervention (professional development) programme, the participants were each asked to complete the POSTT-PS instrument again as a post-intervention POSTT-PS. This was followed by a follow-up to the post-intervention POSTT-PS interview to account for the shifts in the pedagogical orientation. The changes in the scores were accounted for and the interview transcripts were analysed.

Table 3.3: Planning matrix for choice of instruments

Phase	Step	Procedure	Objective	Product
1-baseline	Stocktaking	POSTT-PS questionnaire Interview Classroom observation - EQUIP	To establish the current pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching	Teacher profiles(pedagogical orientation)
2 – planning	Goal setting and Developing strategies	Meeting	To set teaching practice goals towards inquiry.	Goals for each participant
		Meeting	To set strategies for achieving the set goals.	Strategies for achieving the set goals
		Meeting	To identify the type of evidence required to document credible progress towards their goals.	List of documents
3-implementation	Documenting progress towards goals	Classroom observation Stimulated-recall interviews Document analysis	To determine the challenges experienced by Physical Sciences teachers in enacting an inquiry-based teaching approach. To examine shifts in the pedagogical practices of Physical Sciences teachers in inquiry-based teaching due to an empowerment evaluation approach	Field notes Interview transcripts Digital data(videos and pictures) POSTT-PS

3.5.2.1 Pedagogy of Science Teaching Test

The Pedagogy of Science Teaching Test (POSTT-PS) is an instrument developed and validated in the United States of America to assess the knowledge of topic teaching practices that reflect the inquiry nature of science (Schuster et al., 2007). The assessment is multiple choice but differs from the conventional multiple choice where there is only one 'correct' answer and a number of 'wrong' distractors. The instrument instead consists of case-based objective items based on realistic vignettes of classroom teaching situations in science topics. An item presents a realistic teaching scenario for a science topic, poses a question about teaching strategy, and offers response options (Cobern et al., 2014). Figure 3.1 below shows the standard MCQ format of assessment items.

Teaching Vignette	- Realistic classroom situation - The instructional goal is specified - Particular topic content - A particular facet of science - The particular phase of the lesson - One main issue
Question	- Question about possible pedagogy for this situation
Teaching Options A B C D	- Options offer four alternative teaching approaches Or - Comments on teaching approach

Figure 3.1: Standard MCQ format of assessment items (Cobern, et al., Pedagogy of science teaching tests: Formative assessments of science teaching orientations, 2014)

The responses might be evaluations of the teacher's actions, or alternative suggestions as to what the teacher should do next, or ways of handling a particular event (Schuster et al., 2007). The response options reflect the kind of instructional decisions that teachers have to make every day both in lesson planning and on the spot in the classroom. These response options are a spectrum of teaching orientations ranging from direct instruction to open inquiry. Teaching orientations refer to how a teacher tends to design and structure instruction and learning activities, and deal with common classroom events. The instrument (POSTT-PS) has responses that are classified into four main orientations namely didactic direct, active direct, guided inquiry and open inquiry. The orientations are grouped into two groups according to their epistemologies. The first two (didactic direct and active direct) present science as a known product, and the last two (guided inquiry and open inquiry) present science as inquiry. This results in four main science pedagogical categories, spanning a range which we call a science teaching orientation spectrum (Ramnarain, Nampota & Schuster, 2016). The four types of pedagogical approaches are presented in the table below.

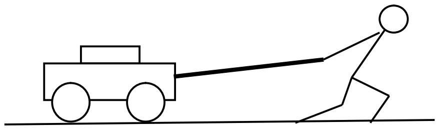
Table 3.4: Descriptions of science teaching orientations

Didactic direct	A teacher presents and explains the science concept or principle directly to learners, and illustrates with examples and/or demonstrations. The learners apply this knowledge to answer questions and the teacher may take learners' questions to clarify any misconceptions. Generally, there are no practical activities in this method, but class discussions on the problem posed by the teacher are a dominant activity.
Active direct	The orientation similarly entails direct teacher exposition, but this is followed by a learner activity based on the presented science content. The activity could be a hands-on practical verification of the concept or principle.
Guided inquiry	The teacher plans an activity where learners explore a phenomenon or idea and, from this, the teacher guides them to develop the desired science concept or principle. The principle or concept arises from the activity and the teacher can explain further or give examples to consolidate. Questions are dealt with using discussion.
Open inquiry	Learners explore a phenomenon or idea on their own, devising ways of doing so. They receive minimal guidance from the teacher, after which they report what they did and found. The teacher facilitates but does not prescribe. The emphasis is on the inquiry process.

Source: (Ramnarain, Nampota, & Schuster, The spectrum of pedagogical orientations of Malawian and South African physical science teachers towards inquiry, 2016)

An example of an assessment item is provided below, with the three divisions as highlighted in Figure 3.1 above. Note that, for illustrative purpose, the options in this example have labels and are presented in spectrum order: didactic direct, active direct, guided inquiry and open inquiry. The labels were omitted in practice and the options were varied from item to item.

Example item



Lesson on force and motion: Ms Brandt is preparing a lesson to introduce her 5th-grade learners to the relationship between force and motion, namely that a net force will cause an object to speed up or slow down (Newton's 2nd Law). The classroom has available a loaded wagon to which a pulling force can be applied. Ms Brandt is considering four different approaches to the lesson.

Thinking about how you would want to teach this lesson, of the following, which one is most similar to what you would do?

A. Write a clear statement of Newton's 2nd Law on the board and explain it carefully for my learners. Then I would demonstrate the law by pulling on a loaded wagon with a constant force in front of the class as they observe the motion. ***(Didactic direct)***

B. Write a clear statement of Newton's 2nd Law on the board and explain it carefully for my learners. I would then have the learners verify the law by pulling on a loaded wagon themselves and confirming what type of motion results. ***(Active direct)***

C. Raise the question of what kind of motion results from a constant force. I would then guide my learners to explore the question themselves by pulling on a loaded wagon and observing what happens. From the evidence, they would then propose a possible law. ***(Guided inquiry)***

D. Raise the question of whether there is any relationship between force and motion. My learners would then be free to explore this safely in the lab. Afterward, we would have a class discussion of their findings. ***(Open inquiry)***

The items can be used both for formative and summative assessment, with both pre- and in-service teachers (Cobern et al., 2014). The South African physical science version of the instrument (POSTT-PS) (Appendix E) has ten multiple-choice questions, each with four responses (A-D) and a space for reasons. The teacher selects the option closest to their teaching style and gives reasons for their answer in the space provided. The teachers' reasons may be either epistemic or practical. The ten items involve different facets of science spanning from learning a new science concept to conducting an investigation. Although these items involve different facets of science, the commonalities in the nature of the pedagogy response options are apparent (Ramnarain & Schuster, 2014). The curriculum appropriateness of the chosen items for the South African curriculum and context was investigated and validity checks were done (Ramnarain & Schuster, 2014). The instrument has been used before in studies in science education both in South Africa and internationally. In South Africa, the instrument was used to identify teachers' science teaching orientations of Physical Sciences at a variety of diverse schools in South Africa (Ramnarain & Schuster, 2014). Internationally the instrument was used to investigate and compare the pedagogical orientations of Physical Sciences teachers in Malawi and South Africa towards inquiry or direct methods of teaching science (Ramnarain, Nampota & Schuster, 2016).

In this study, the POSTT-PS instrument was used to examine the pedagogical orientation of Physical Sciences teachers towards science teaching. Research by Lederman, Abd-El-Khalick, Bell and Schwartz (2002) has highlighted a common disadvantage of using MCQ assessments, as pre-selected responses cannot cater for all possible viewpoints. To counter this in terms of the POSTT-PS, Cobern et al., (2014) acknowledge the presence of a variety of science teaching strategies, but further indicate that these strategies are variants of two fundamental epistemic modes of instruction: either a form of inquiry or a form of direct instruction. This means every teacher's kind of response is represented among the given responses. In an effort to further understand the reasons for selecting and not selecting some of the responses an interview was scheduled immediately after completing the instrument. In the follow-up to the POSTT-PS interview, the teacher was asked to give their reasons for either selecting or not selecting each response.

3.5.2.2 Interviews

An interview is a purposeful conversation directed by one person in order to get information from an individual or a group of people (Bogdan & Biklen, 1998). The researcher wants to find out what is "in and on someone else's mind" (Patton, 2002:341). Interviewing is the best technique to use when conducting intensive case studies of a few selected individuals (Merriam, 2009:88). The researcher must establish a good rapport with the participants. Detailed and rich information is mostly obtained in a conversation when both conversational partners get along (Boeije, 2010). It is the researcher who is mostly responsible for creating trust and openness. This enriches the data and provides valuable depth and insights, which may not have been achieved using other forms of data collection. If the researcher wanted more explanation, justification or rationalization then it could be asked and answered immediately by the participant. Interviews give the researcher the opportunity to find out from participants those things that cannot be directly observed (feelings, thoughts and intentions) or past behaviours (Patton, 2002). An interview was preferred since it can get better data or more data at less cost than other methods can.

Interviews can be distinguished from one another by their predetermined structure and the extent to which the interviewer and the interviewee determine the contents and flow of the interview (Boeije, 2010). Opie (2004) identified three types of interviews: namely structured, semi-structured and unstructured. On one end of the continuum we have the structured which is entirely pre-structured, thus the wording and order of interview questions are predetermined. In qualitative studies, it is usually used to obtain demographic data (Merriam, 1998). At the other end, we have the unstructured, sometimes referred to as free-interview. It has open-ended questions normally used if the researcher does not know enough about a phenomenon and can use it to formulate questions for later interviews.

A qualitative researcher is looking for a true understanding of what is happening, thus the interviews are left neither entirely open nor entirely pre-structured in terms of content, formulation, sequence and answers (Boeije, 2010). Semi-structured interviews (Appendix I) were utilized in this study. Semi-structured interviews allow the researcher to respond to the situation at hand, to the emerging worldview of the respondent, and to new ideas on the topic (Merriam, 2009).

In this study, one-on-one interviews were conducted with all the participating Physical Sciences teachers. The researcher used the interviews to gather descriptive data in the participant's own words. The focus of the conversation was on questions related to the research study. The aim was not to elicit answers from the interviewee, but rather to make it possible for the participants to share their story regarding a particular phenomenon. A total of eleven interviews were conducted with each teacher. The first three interviews were conducted in the initial stages of the study to establish each participant's pedagogical orientation. These interviews were done after the teacher had completed the Pedagogy of Science Teaching Test (POSTT-PS) instrument. The interviewed teachers were probed in detail on their responses to the POSTT-PS items. Each teacher was asked to justify the option chosen and to explain the reasons for not choosing the other options. Eight interviews were conducted during the intervention stage to assess the progress and review strategies to determine their effectiveness and appropriateness. The last of these eight interviews were done to review the accumulated evidence in light of the set goals. All the interviews were recorded and transcribed. This included a discussion of the factors that could have resulted in the participant failing to achieve some of the goals. In qualitative research, interviews may be used in two ways: as a dominant strategy for data collection or in conjunction with other techniques (Bogdan & Biklen, 1998). In this study, interviews were employed in conjunction with document analysis and classroom observation.

3.5.2.3 Classroom Observations

Observation is one of the key methods for data collection in qualitative research (Creswell, 2013). There are a number of roles an observer could play. At one end of the spectrum is a full participant. Here the researcher is fully engaged with the participants - covert research. This is sometimes favoured for the potentially greater rapport between the researcher and participants. At the other end is a complete or full observer whose participation and research status is unknown. A good qualitative researcher stays somewhere between these extremes (Creswell, 2013).

Participant observation provides certain unusual opportunities for collecting data from the viewpoint of the participant. Participant observation is useful when (Jorgensen, 1989):

- little is known about the phenomenon;
- the emic and etic perspectives are opposed or stereotyped;

- the phenomenon is somehow hidden from outsiders' views.

The method is challenging in that it taxes the researcher's social skills and memory. The researcher needs to balance the two different roles, being a participant and an observer at the same time. Critics of participant observation point to the highly subjective and therefore unrealistic nature of human perception. It may be distracting for the researcher to record data when he or she is participating in the activity (Creswell, 2013:167). In this study, the researcher assumed the role of an evaluator, this role required the researcher to observe and evaluate the progress of the lesson. This entails evaluating the participant based on the types of strategies used in supporting learners doing inquiry. This entailed completing an EQUIP observation protocol and required the researcher to record data without direct involvement in the activity or with the participant.

Observations take place in the natural setting where the phenomenon of interest occurs, which is the classroom. The researcher can record behaviour as it is happening. In this study, the focus was on documenting teacher progress in the inquiry-based teaching of Physical Sciences. This method of data collection allowed the researcher to have a first-hand encounter of the phenomenon of interest. It is the best method to use when the activity can be observed first-hand, although a number of challenges have been cited in the literature. The major challenge being the presence of an observer in a classroom may be obtrusive (Bogdan & Biklen, 1998). Others have suggested that over time, the stability of a social setting is rarely disrupted (Merriam, 2009). If noticed, the researcher needs to identify those effects and account for them when interpreting data. The theoretical framework and research questions determine what to observe. Since the study was qualitative in nature, the researcher did not necessarily decide beforehand what exactly was going to be observed, but had a clear purpose that guided the whole process. The purpose of the observation was to understand the extent to which the professional development programme had an influence on the classroom practice of the teachers in inquiry-based teaching.

The teacher was observed in class teaching Physical Sciences to learners eight times as a way to collect evidence to be used to evaluate progress towards the set goals. All the participants were observed in the classroom as they taught the Physical Sciences. The first observation was in the initial stages of the study to triangulate emerging findings from the Pedagogy of Science Teaching Test (POSTT-PS) instrument and interviews on the teacher orientation. The observations were also conducted during the intervention stage (when the teacher undergoes the professional development) as a tool to record behaviours or teaching practice. These records of behaviours were then used as a reference for future interventions or interviews. The researcher used an EQUIP classroom observation tool to help in the capturing of the selected behaviours. The researcher used an audio recorder and a camera to help capture activities as they occurred in order to aid the writing of field notes on the observation.

Teachers in the study were observed eight times over a period of one year and field notes were produced for each teacher. The purpose of the observation was to understand the challenges encountered by the teachers in inquiry-based teaching and the extent to which the professional development influenced classroom practice.

3.5.2.4 Document Analysis

The term document is an umbrella term to refer to a wide range of written, visual, digital and physical material relevant to the study at hand (Merriam, 2009). Documents are valuable as a source of information and also as a stimulus for paths of inquiry that can be pursued through interviews and observations (Merriam, 2009). Besides eliciting further discussions, documents are also a good check on the information obtained in the interviews. They can also be used to supplement data gathered through interviews and observation. Documents give us a snapshot of what the participant thinks is important and can reveal to the researcher the inner meaning of everyday events. The documents are a product of a subjective view of the participant who selects what to and what not to include.
They are sometimes far from what really transpired but reflect the participant’s perspective, which is what a qualitative researcher is looking for. In the last decade or so there has been a growing interest in using visual documents as data sources (Stanczak, 2007). Visual documents (videos) were used in this study to stimulate recall during interviews or discussions after observing a lesson. The videos were

researcher generated. A distinction is made between documents that were present before the study and researcher-generated documents (Bryman, 2008). The latter are documents prepared by the researcher or for the researcher by participants after the study has started. Videos have the advantage of unlocking the subjectivity of those who observe the events. They also capture non-verbal behaviour. The main document that was analyzed was the teacher's lesson plan. The lesson plans for the selected few lessons when the teacher was implementing the strategies were analyzed. A few other documents like the science laboratory inventory and learners' work were checked to validate the observations.

3.5.3 Data Analysis

The researcher utilized an inductive analysis of the qualitative data, where theories become emergent as the data is discussed and analyzed. This bottom-up approach means that the theory must be grounded in the data and therefore the findings are taken for what they are. Segmenting and reassembling are considered the chief activities of qualitative data analysis. Coding was used to categorize the data transcribed from the interviews. Coding is a process of defining what the data describes (Charmaz, 2006). This is a process of breaking down, examining, comparing, conceptualizing and categorizing data (Strauss & Corbin, 2007). A summarising phrase, name or label for a segment of data is ascribed and accounts for each piece of data. These labels are normally placed at the beginning of the data analysis. The codes normally come from everyday language, the field-related concepts or the participant's terminology (in vivo codes). The researcher reads through the whole passage and then attaches labels line by line. Codes were assigned to segments of the text, a process known as open coding. The researcher applied manual coding and no computer-assisted software programme was used.

After open coding, data are put back together through a set of procedures commonly referred to as axial coding. This is achieved by making connections between categories (Strauss & Corbin, 2007). It reassembles data that was fragmented during open coding to give coherence to the emerging analysis (Charmaz, 2006). The primary purpose of axial coding is to determine dominant elements in the research. The second purpose is to reduce and reorganize the data set (Boeije, 2010) and the result of axial coding is a list of categories. Themes were then generated from these categories. The process of going from codes to themes is described visually by Saldana (2009) below in Figure 3.2.

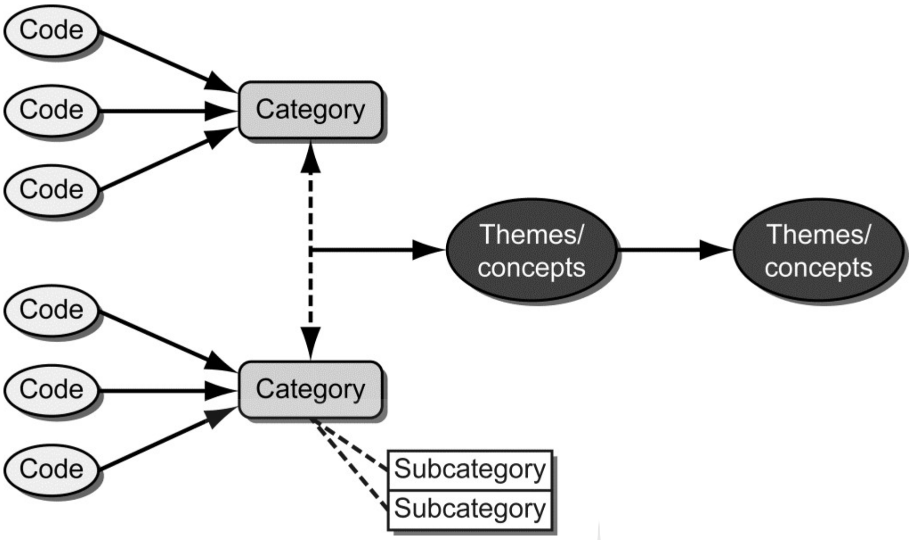


Figure 3.2: Saldana's codes theory model for qualitative inquiry, Saldana (2009)

3.5.3.1 Data Analysis of the POSTT-PS Instrument

The multiple-choice responses are coded into the four pedagogical orientations namely didactic direct, active direct, guided inquiry and open inquiry. Each orientation is allocated a number from 1 to 4 respectively. It is of paramount importance to note that this convenient ordinal labelling of the four orientations is not meant to imply any defined measurable ratio relationship between them. The teachers' responses to each item were translated into the corresponding number (score); thus each participant has ten scores for the ten items. The sum of the ten scores was found and then a mean score for the distribution of responses was calculated for each participant. The spectrum of pedagogy orientation was on a scale of 1 to 4, with didactic direct assigned 1, active direct 2, guided inquiry 3 and open inquiry 4. The mean score is determined along this scale and the overall pedagogy orientation mean for each teacher was determined. This mean became the measure of the most preferred teaching orientation for the teacher. The reasons for choosing each item response were coded and themes were established to explain the science teaching orientation. The teaching orientation profile was kept for each teacher as a baseline.

3.5.3.2 Data Analysis of the Interviews

All the interviews were audio recorded and transcribed verbatim. The qualitative data were coded and classified, a process that involved reading through interview transcripts in order to have a comprehensive overview. The codes that reflect conceptual relationships were assigned. The codes were not predetermined, but emerged from the data. The raw data was examined and names of codes were developed. This is known as open coding and is followed by axial coding where the initial open codes were related to each other, rearranged and reorganised by making connections. Finally, selective coding was done. This involved choosing the most appropriate and important categories, relating them to other categories, validating those relationships and filling in categories that needed further refinement and development. After coding all the data, the codes sharing the same meaning were grouped together into sub-themes, which were eventually grouped together into themes.

3.5.3.3 Data Analysis of the EQUIP

The teachers' overall inquiry instructional practice was scored based on the four categories, as depicted in each lesson EQUIP tool; instructional factors, discourse factors, assessment factors, and curriculum factors. Each teacher's mean score for the EQUIP was calculated by scoring each of the nineteen indicators and finding the mean score by dividing the total score by the number of indicators. Since the levels of inquiry were along a scale of 1 to 4, with pre-inquiry assigned 1, developing inquiry 2, proficient inquiry 3 and exemplary inquiry 4, then the mean score was determined along this scale. This mean became the measure of the degree of inquiry teaching for each teacher.

3.6 Ethics

Ethics in research are the principles of right and wrong that set forth a moral position of a group of individuals at a particular time (Bogdan & Biklen, 1998). Ethics are concerned with finding a balance between benefits and risks (Boeije, 2010:43). Social scientists follow ethical rules not only to prevent them from doing harm to others but to protect themselves. Three issues dominate the official guidelines in research with humans: informed consent, privacy and confidentiality, and anonymity. Permission for this study was granted by the ethics committee of the University of Johannesburg. The research proposal, informed consent forms, and the instruments to be used accompanied the application. The committee approved the conduct of this study, in ethics clearance number 2014-006 (see Appendix A).The ethics certificate was then used to apply for access to the schools.

3.6.1 Gaining Access

Permission to conduct research at the schools was obtained from the Gauteng Department of Education (see Appendix B). Further permission was sought from the principals of the schools where the participating teachers were selected (see Appendix C). The principals were furnished with the details of the research and assured that the research was not going to disturb the smooth running of the school.

3.6.2 Informed Consent

The researcher has an obligation to inform the participants that they are being researched so they can decide if they wish to give their consent (Bulmer, 2008). Participants were informed about the nature and purpose of the research, including the data collection methods, benefits, and risks of participating in the study. This was done in such a way that they gave their consent freely with understanding. A signed written agreement was taken as evidence of the participant’s informed consent. Additional informed consent was sought verbally during data collection when there were slight deviations from the original plan. The participants were informed of their right to withdraw at any time of the study and assured through informed consent that their identities would remain confidential.

3.6.3 Confidentiality and Anonymity

An agreement was made with the participants on how the data would be handled to ensure privacy and anonymity. Pseudonyms were used to ensure the confidentiality of the participants’ identity. The original digital recording is kept in password secured folders and the transcripts are kept in a securely locked filing cabinet.

3.6.4 Privacy

Privacy refers to the interest of individuals to control the access that others have to them. The participants were assured of their right to privacy and that the researcher would not disclose any information about them to others. If the researcher wanted to use any information provided by the participants or observations made by the researcher during informal interactions, the participants' consent had to be obtained. This was important to assure the participants that they would not be observed secretly.

3.6.5 Ethical Issues on Analysis

The researcher made sure that trust was established and maintained during the process of data collection between him and the participants. The participants gave information freely. This increased the quality of the data. The researcher was careful to analyze the data and seek guidance when the need arose to avoid erroneous findings that may harm any of the stakeholders. The researcher did a thorough analysis to ensure credible findings that represented the emic perspectives of the participants.

3.7 Validity and Reliability

Ensuring validity and reliability in qualitative research involves conducting the investigation in an ethical manner (Merriam, 2009:209). The two important indicators for the quality of research are reliability and validity. Reliability refers to the rigour, consistency and above all trustworthiness of the research (Wilson, 2013). In qualitative research, the term may not have the same meaning it carries in quantitative research since the process of data collection and product are intricately linked. In addition to that, the role of the researcher in qualitative research is not merely instrumental but constitutes an integral part of the findings themselves. Validity refers to the extent to which a study measures what it intends to measure. The following validity and reliability checks recommended by Merriam (1998) were used during the study.

3.7.1 Triangulation

Triangulation refers to the examination of a social phenomenon from different angles. It entails the use of more than one method or source of data in a research endeavour (Bryman, 2008). Different sources of data and data collection methods were used to confirm emerging findings. Many sources of data in a single study lead to a fuller understanding of the phenomena under study (Bogdan & Biklen, 1998). Triangulation can be expanded into using multiple participants, multiple researchers, different theoretical approaches and different data collection techniques. This study utilized different data collection methods (interview, observation and document analysis) and theoretical triangulation. Theory triangulation is the analysis and comparison of two or more theoretical positions relating to the research problem. In effect, researchers normally undertake a degree of theory triangulation as a matter of course when undertaking a literature review prior to collecting new empirical data. The theory triangulation informs the research plan. Theory triangulation thus involves looking at the research situation from different theoretical perspectives. For example, in this study two theories were adopted to interpret the data, namely constructivism, and Ausubel's theory of learning and instruction. The assumption is that, by applying more than one theoretical approach, a better understanding might evolve. This study produced test data, interview transcripts, records of classroom observations, and artefacts such as lesson plans, learner support materials used by the teacher and written tasks completed by the learners. These were all used to better understand and crosscheck the data generated by each method. This measure served to ensure a layered in-depth description of the subject under study.

3.7.2 Member Checks

Data and tentative interpretations were checked with the teacher. The transcribed interviews and field notes were presented to the participants to verify the information. Additionally, information on preliminary results was discussed with the participants. This gave the participants an opportunity to check the accuracy of the data to ensure that what was captured was a true reflection of the phenomenon observed.

3.7.3 Peer Review

There was an ongoing dialogue and critical reflection with other researchers on the research process and tentative interpretations. This was important to incorporate control on each other's interpretations. Another researcher can bring new input into the discussion because of different professional and personal knowledge, and experience. Teams can foster a higher level of conceptual thinking than individuals working alone can.

3.7.4 Reflexivity

Critical self-reflection regarding anything that might bias the interpretation, e.g. hidden assumptions, own worldview, theoretical orientation, and interrelationships with the teacher, was carried out. This was done to ensure that the researcher's impact on the research process was kept to a minimum. The researcher's personal and professional characteristics were written down. The researcher had to guard against becoming too involved with the participants because of the prolonged stay at the sites.

3.7.5 Audit Trails

A detailed account of methods, procedures, and reasons for decisions was provided. Koch (2006) suggests that a study's trustworthiness may be established if a reader is able to audit the events, influences and actions of the researcher. There are two types of audits, physical and intellectual. The physical audit trail documents all key stages of a research study and reflects the key research methodology. The intellectual audit trail, on the other hand, outlines how a researcher's thinking evolved throughout all phases of the study. The audit trails make all the critical decisions taken throughout the research process transparent.

3.7.6 Rich Description

A detailed description of events was provided to enable readers to contextualize the study and judge the extent to which the findings could apply to their situations. The report includes descriptions of the context, the participants involved, and the activities of interest. In addition, data, in the form of quotes from documents, field notes and interviews, and excerpts from videos are included in support of the findings (Merriam, 2009).

3.8 Chapter Summary

The purpose of this chapter was to present and explain, the research design and methodological approach of the study. The chapter reflected on the mixed methods design and the justification of the research methods employed in the study. An outline of the research paradigm and the actual methods used to collect and analyze data was given. Data sources such as semi-structured interviews, classroom observation, and POSTT-PS instrument were employed to answer the single research question for the study: How can an empowerment evaluation approach influence and shift the practice of Physical Sciences teachers towards an inquiry-based pedagogy? The chapter discusses the quantitative data sources and qualitative data sources and the integration of the data during analysis and interpretation. The framework for data analysis and presentation of research findings were discussed.

CHAPTER 4: TEACHER PROFILES OF PEDAGOGICAL ORIENTATIONS

4.1 Introduction

In the previous chapter, the methodology and research design were discussed. This chapter is divided into two sections and presents findings on the first phase of the study, whereby a baseline was established on the teaching practices of the three teachers. The first section is a summary of information gathered through the POSTT-PS instrument. The second section presents case profiles for each of the three study participants. The case profiles presented are based upon multiple data sources including a follow-up interview on POSTT-PS responses, semi-structured interviews on teacher current practice and data from classroom observations of participants teaching a Physical Sciences lesson.

Each case profile begins with a snapshot of the individual participant's educational and teaching background and their current teaching context. This is followed by the summary of teacher beliefs. The case is then concluded with a participant teaching vignette and science teaching orientation. Classroom vignettes are presented to capture the essential elements of the participant practice and interaction with the learners in an effort to succinctly portray the pedagogical practice of the teacher participant. The purpose of the cases is to provide an in-depth profile of the study participant's science pedagogical orientation. The cases are based on my interpretation of the teacher participants' pedagogical orientation in a manner reflective of the Cobern et al. (2010) science pedagogical orientation continuum (model).

To come up with the teacher profiles I analysed participant teachers' responses with respect to three data sources collected at three separate times, which are an interview transcript for the follow up to POSTT-PS; field notes for preliminary classroom observation; and interview transcripts for the teacher current practice. The intent is to capture and succinctly portray the individual teacher conceptions about teaching, learning, learners and inquiry-based teaching held at the beginning of the study. According to Mansour (2009), conceptions encompass teacher beliefs and teacher understandings. These conceptions were constantly re-examined to ascertain how they might have changed, been challenged or developed as a result of the study. The information is used to characterize each individual and will help the researcher to understand the participant responses and biases that could emanate from their own subjective view of the world. A summary of the teachers' beliefs is extracted from the teachers’ reasons for or against a certain teaching orientation- didactic direct, active direct, guided inquiry and open inquiry (DD, AD, GI, and OI). As the teachers express themselves and their teaching experiences they expose the researcher to their challenges and contextual factors that mitigate against the teaching and learning of science through inquiry. Each participant, therefore, becomes a case and background information for each participant is presented for each case as a foundation to help create an overall picture of each individual. Following this, a brief description of the participants’ general views on the teaching and learning of science is given. The findings presented in this chapter address research objectives one and two:

- To establish the current pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching; and
- To determine the challenges experienced by Physical Sciences teachers in enacting an inquiry-based teaching approach.

4.2 Pedagogical orientations revealed by POSTT-PS

The pedagogical orientations of teachers were investigated by collecting and analysing teacher responses to the POSTT-PS instrument. The instrument was used to examine individual participants’ preferences for inquiry-based teaching. The data generated by the instrument together with the follow-up interviews helped to establish each teacher’s current pedagogical practice in inquiry and the challenges experienced in enacting inquiry-based teaching. An in-depth examination of the pedagogical orientation to teaching science gave me insights into the individual thoughts and conceptions of inquiry-based teaching.

I utilized the POSTT-PS to elicit the teacher participants' particular pedagogical orientation towards teaching science: Didactic direct, active direct, guided inquiry and open inquiry. The POSTT-PS instrument has ten questions and each question is divided into two sections. The first section involves a teaching scenario such that the participants will envision themselves teaching a particular topic and select one of the four pedagogical choices that followed. Each pedagogical choice corresponds to one of the science teaching orientations: didactic direct, active direct, guided inquiry and open inquiry. The second section is an open-ended response asking participants to write their reasons for their instructional choices and say why they did not choose the other options. This open ended response is likely to prompt a lively discussion during the follow up to POSTT-PS interview (Cobern et al., 2014). The interview serves to draw out other critical ideas or issues not present in the response options such as contextual factors and the constraints that might have an influence on teacher pedagogical practice. During the interview, participants are asked to elaborate on their reasons for their instructional choices and say why they did not choose the other options. The rationales given for specific decisions are pursued and their worth assessed. This was done for each participant to elicit the participants' particular orientation towards teaching science: didactic direct, active direct, guided inquiry and open inquiry.

The science teaching orientations above fall along a continuum ranging from a teacher-centred (direct) approach to a learner-centred (inquiry) approach to science teaching. The 'didactic direct' and 'active direct' orientations refer to the more traditional teacher-centred orientations, such that the teacher directs all the learning activities. The two are different in the sense that the didactic direct orientation is entirely teacher-oriented exclusively of learner interactions. The active direct orientation consists of learners engaging in hands-on activities and confirmatory investigations. In this study, those who indicated these teaching orientations were categorized as having a direct instructional approach. Those with an inquiry orientation (guided or open) would indicate preferences in teaching methodologies that are learner-centred and allow learners to explore phenomena in a hands-on, minds-on manner (Ward, 2016). The learner will be afforded autonomy and responsibility for their own learning. The two orientations differ on the level of guidance provided by the teacher. During the guided inquiry the teacher provides learners with a problem to investigate, but the methods for resolving the problem are left to the learner. For example, the teacher gives guiding questions and the learner makes decisions on how to explore and analyse data. In an open inquiry, learners are entirely responsible for initiating and conducting their own investigations, starting from the investigative question. Thus with open inquiry, learners investigate phenomena of their choice.

The individual results were compiled and tallied into frequencies of teaching orientations; DD, AD, GI, and OI. A mean score was calculated for each participant and is indicated in Table 4.1. The primary purpose of Phase One was to ascertain the participant pedagogical orientation at the beginning of the study and use their choices to further interrogate their teaching practice in the inquiry. Each vignette on the POSTT-PS item was followed by a single open-ended question that asked the participant teacher to explain their rationale for their pedagogical selection. I then analysed their open-ended responses to the POSTT-PS to validate their pedagogical choices. Their science teaching preferences together with their corresponding rationales were established through the analysis of the data gathered from the POSTT-PS instrument and the follow up to the POSTT-PS interview. Once established, the teaching orientation profile serves as the participant's baseline.

This premise of ascertaining the participants' baseline is a requirement of the empowerment evaluation technique. In empowerment evaluation this step is called 'taking stock' and it includes determining the participant's current position in light of the individual's strengths and limitations. According to Ausubel (1968), it is important to ascertain what the learner knows before any teaching so that this knowledge can inform the teaching. My study involved a professional development of Physical Sciences teachers in inquiry-based learning, thus the need to know the participating teachers' current pedagogical practices and what informs their practice, beliefs (conceptions) and understandings in inquiry science teaching and learning at the beginning.

Table 4.1 presents results from the responses to the POSTT-PS instrument administered to the participant Physical Sciences teachers in the study. These teachers participated in a case study that investigated the pedagogical practices of three teachers in three different township schools in South Africa. The table gives the descriptive statistics for teachers' pedagogical orientations. For each participant the percentage of responses for the four teaching approaches over the ten items is presented. This is followed by the mean of the participant's responses as determined by POSTT-PS responses. The mean was calculated from the ten scores that were obtained by assigning a corresponding number (from 1 to 4) to each of the ten responses. The sum of the scores was then divided by the number of items to give the mean value for the distribution of responses. The resulting value (which is between 1 and 4) is a measure of the degree of inquiry teaching orientation of the teacher. Since the spectrum of orientations was along a scale of 1 to 4, with didactic direct assigned 1, active direct 2, guided inquiry 3 and open inquiry 4, the obtained mean value only reflects the degree of inquiry teaching orientation. The POSTT-PS scale (DD to OI) reflects the increased degree of inquiry teaching mode, coincident with the decreased degree of direct teaching mode (Cobern et al., 2014). It is important to note that the POSTT-PS scale is an ordinal interval scale and does not suggest any mathematical (ratio) relationship between the teaching approaches. The numbers 1 to 4 do not suggest an inferior to superior approach, but a simple way to show an increasing level of inquiry. Thus the resulting means and standard deviations are simple descriptions of central tendency and dispersion within the individual's item responses. The overall mean of responses for Mr. Charles was 2.3 with the standard deviation of 0.64. The standard deviation represents the spread in the responses, with a small (near zero) standard deviation indicating a narrow distribution, while a bigger (near one) standard deviation indicates a wider distribution of responses. In interpreting this way, Mr. Charles's responses centred on active direct and are fairly spread around the active direct approach to teaching. Mr. Moloku's mean value of 2.9, with a standard deviation of 0.54, is an indication of responses centred on slightly guided inquiry and fairly spread. Mr. Kapok has the mean of 2.7, with a standard deviation of 0.90. A quick comparison of means confirms that Mr. Kapok and Mr. Moloku leaned towards the inquiry side of the spectrum while Mr. Charles is more towards the non-inquiry. One would want to know the reasons given by the teachers for their choices. This is critical, especially considering the study needs to use the information to improve practice; thus the critical friend would need to know what reasons the teachers have for their choices. The standard deviation is the descriptive measure of the diversity of opinion, which in my study could be a measure of the level of the factors that influence the choice of a teaching approach. A higher standard deviation such as that of Mr. Kapok suggests the presence of diverse considerations when choosing a teaching approach. The names used in the table are all pseudonyms.

Table 4.1 Descriptive statistics on the pedagogical orientations of each participant teacher

	Didactic direct (%)	Active direct(%)	Guided inquiry(%)	Open inquiry(%)	Mean orientation	Standard deviation
Mr. Charles	10	50	40	0	2.3	.64
Mr. Moloku	0	20	70	10	2.9	.54
Mr. Kapok	10	30	40	20	2.7	.90
Overall	6.67	33.33	50.00	10.00	2.63	.75

Overall, the participants indicated a very small percentage preference for didactic direct, with the overall percentage being around 6.67%. This was calculated from the number of responses that were falling in the DD as a percentage of the total number of responses. This may suggest that didactic direct is not a preferred teaching approach for these teachers. The other teaching approach that exhibited a low percentage preference for the three participants was open inquiry. It has a low percentage (10%), although higher than didactic direct. Active direct and guided inquiry were found to be the most preferred teaching approaches by the three teachers: 33.33% and 50% respectively. This agrees with the findings by Ramnarain & Schuster (2014) in a study conducted in South Africa which regards active direct and guided inquiry approaches as the most preferred methods for township and suburban teachers respectively. Of the three teacher participant combined responses, 60% of responses were inquiry and only 40% were non-inquiry. This was calculated from the number of responses that were falling into inquiry (GI and OI) and non-inquiry (DD and AD) as a percentage of the total number of responses. Mr. Moloku had 80% of responses falling in inquiry, followed by Mr. Kapok with 60% of responses being inquiry. It is only Mr. Charles who had only 40% of his responses in inquiry.

The differences in the teachers' responses could be an indication of different contextual factors or differences in their conceptions about teaching and learning of sciences. The POSTT-PS instrument consists of items representing more than one construct, therefore one must bear in mind that different teaching situations may evoke different pedagogical orientations (Cobern et al., 2014). Thus the variations in individual teachers' responses may be a result of the different teaching scenarios presented by the items. These items can be expected to prompt lively and diverse discussion of alternative teaching approaches. The response spread for the items raises other interesting questions. Does the area of science, grade level or particular topic make a difference in response to an item? These questions are relevant in understanding the reasons for preferring one type of pedagogy over another. Of great interest to this research are the reasons teachers give for their choices. It is these intriguing differences between the different teachers' responses that are worth studying. The instrument POSTT-PS precipitated a range of responses from the three teachers in the study and each teacher chose some range of response types for different items, suggesting that classroom discussions based on these items could usefully indicate how the teachers understand and value different approaches to science pedagogies, and under what circumstances they believe they would employ them. Such discussions, coupled with the ability to analyse the reasons for and against each response, should help the researcher gauge individual teachers' current standing in term of understanding science pedagogies.

4.3 Profiling teachers' pedagogical orientations

In this study, the first two orientations (didactic direct and active direct) are considered as variants of the same fundamental mode of instruction and participants who indicated these teaching orientations were categorized as having non-inquiry orientation. The other two (guided and open inquiry) are inquiry orientations and participants who indicated these orientations were categorized as having inquiry orientation. Non-inquiry orientations are traditional teacher-centred orientations, where communication flows from the teacher to the learner and teacher talk dominates the lesson (Lehesvuori, Ramnarain & Viiri, 2017). Even though they are both teacher-centred; didactic direct and active direct are different. Didactic direct is entirely teacher directed, while active direct has an additional component of learners engaged in hands-on activities which may include verification type of investigations. It is important to note that the term ‘direct’ may be conflated with ‘direct passive’ or ‘direct rote’ learning, but direct instruction does not preclude cognitive engagement. The inquiry orientations are learner-centred orientations to the teaching of science. Learners have significant autonomy and responsibility for their own learning. The teacher is not a ‘sage on the stage’, as in non-inquiry, but a facilitator. During the guided inquiry the teacher initiates the learning process by providing an investigative question and the learners conduct their own investigations, record and communicate their findings. In an open inquiry the learners investigate a raw phenomenon in their own way and communicate their findings.

In the interviews that followed the analysis of POSTT-PS, the participants elaborated the reasons for these choices. The data from these follow-up POSTT-PS interviews were coded and analysed to come up with reasons that account for certain teaching orientations. This was a way of eliciting their beliefs in science teaching and learning, especially in terms of inquiry and non-inquiry. Beliefs are personal constructs that are important to the individual, in this case, the teacher. This would provide a full account of and insight into the basis of their orientation, especially what might be influencing their orientation. Understanding their thoughts and motivations concerning each teaching orientation (inquiry and non-inquiry) could shed valuable light on why inquiry-based teaching and learning are not yet a preferred method of teaching in most science classrooms.

The POSTT-PS responses reflect teacher perceptions of the most effective approach to teach a certain concept and the reasons for this choice. The data gathered by the POSTT-PS instrument, the follow-up interview and the preliminary classroom observation enabled me to compile a profile of each teacher. The profiles constitute a baseline against which shifts in pedagogical practices due to empowerment evaluation could be established. These profiles are presented in the following sections and are based on teaching background and context, teaching beliefs, a lesson observed and analysed using the EQUIP observation tool, results from POSTT-PS and interviews. All names below have been made anonymous.

4.3.1 Profile of Mr. Charles

Mr. Charles's profile is presented in this section in terms of his teaching background and beliefs. These were extracted from qualitative data from analysis of semi-structured interview transcripts. The analysis of quantitative data from the EQUIP for the first classroom observation culminates in the individual teacher vignettes. Lastly comes the interpretation of Mr. Charles's pedagogical orientation as informed by the POSTT-PS and a follow-up to the POSTT-PD interview.

4.3.1.1 Teaching background and context

Mr. Charles, a man in his fifties, enjoys teaching Physical Sciences and working with his high school learners. He thinks what made him end up being a teacher was the interest probably instilled in him by his high school science teacher. He says: "I can't say there was much of inquiry in what he was doing, but what he was doing instilled in me what I can call the world of science." Mr. Charles started his teaching career at a rural school, before enrolling for a teacher training course. He taught at the rural school for two years, then proceeded to university for his Bachelor of Education four-year degree. In addition to his bachelor's degree, he has an Advanced Certificate in Education - Physical Sciences (ACE). During his teaching practice for the undergraduate degree he worked at a polytechnic school attached to a ceramics production company. He used to frequently take his learners to the production company for educational tours. He has undergone several in-service courses offered by the department of education. He served as a Science Department head for four years, monitoring curriculum and assessment, and mentoring new teachers.

He is from Zimbabwe and has been a science teacher for more than 25 years. He has been teaching Physical Sciences in South Africa for the past 13 years. Mr. Charles is in his third year after joining Ruth High School, a school he was teaching in at the time of the study. Ruth High School is a township school in South Africa located near an informal settlement. The majority of the learners in the school are black and come from the informal settlement next to the school. The school does not have laboratories and Mr. Charles uses the classroom as a laboratory. He has between 40 and 55 learners in a class, well above the department of education learner-teacher ratio of 30/1. Mr. Charles is teaching Physical Sciences (grades 10-

12) and Natural Sciences (grade 9) at the school. His school is relatively new and still uses mobile classrooms. His mobile classroom is bright and clean but fully packed with desks and a small cabinet in the corner for storage. The classroom contains a traditional arrangement of learner desks in five rows of nine desks each, facing a chalkboard at the front of the classroom. During an experiment they combine desks and form bigger tables which they surround in groups to observe the results.

4.3.1.2 Teaching beliefs

Research on teacher beliefs has established that teachers hold complex beliefs that influence how they view learners, themselves and science. Analysis of qualitative data from the semi-structured interviews (Appendix I) in Phase One gave an insight into the individual teacher beliefs. To establish the influence teacher beliefs have on practice, Bryan (2003) profiled six major categories of beliefs about science teaching and learning which she found defined practice: (a) the value of science and science teaching, (b) the nature of science and goals of science instruction, (c) control in the science classroom, (d) how learners learn science, (e) the learners' role in the science classroom and (f) the teacher's role in the science classroom. I describe Mr. Charles's teaching beliefs by addressing aspects of his instructional practice in terms of Bryan's six major categories of beliefs about science teaching and learning.

The value of science and science teaching: Mr. Charles believes science is there to better the lives of the learners and the communities they come from. He explained:

> Learners analyse the quantitative and qualitative aspects of objects or phenomenon in order for them to use that knowledge to better their lives or those of other people. I mean the purpose of teaching would be for learners to see that and they use that scientific knowledge to better the lives of the community.

Mr. Charles perceived science as providing solutions and explanations for the problems facing the communities. He has believed science is a body of knowledge and a way of knowing at the same time. He emphasized that science is a problem-solving method that relies on evidence. He explained: “Nowadays, when we talk of science it is an approach to any field of study. We used to have arts subjects, but they also used science in order to investigate things there.” Here we see Mr. Charles associating science with investigations. When asked how he preferred to teach science, he indicated the importance of concept development through experimental work:

> I develop a concept if that concept is linked to a practical that I can do better. In that science lesson I should have learner participation right, they must indicate through their participation how they are understanding the lesson and then lastly there should be an assessment of whatever you were treating that lesson in order for you to plan ahead and also ascertain that whatever was being learned had some impact on the learners.

The nature of science and goals of science instruction: Mr. Charles does not believe in the tentative nature of science. In an interview on investigations he portrayed a picture of the permanency of science. He explained: “There is nothing new that the learners will be trying to find out except to repeat what has been done by scientists and verify that it is true and does happen that way”.

I identified three overarching goals for his teaching. His first goal is to act as a resource person and provide content knowledge through lectures and worksheets for laboratory investigations. The second goal is to integrate practical work in the form of demonstrations, experiments or simulations. In an interview on investigations, Mr. Charles explained:

> Learners have to carry out a practical in order to ascertain certain conclusions about science. To see that thing in a practical induces in the learner a copy of that information that is less easily erased than to theorise about concepts in physical science.

His third goal is to link the science with the everyday situation of learners so that learners can see the role of science in their lives.

Control in the science classroom: Mr. Charles believes that a teacher must have control of all the activities in the classroom. He perceives the teacher as an authority on knowledge who should not be questioned or second-guessed by the learner. This is revealed in the excerpt below:

> Learners should not doubt you because sometimes things of science are difficult to comprehend, and later they say you know what, meneer is lying.

The perception is of the teacher in possession of information that he has to give away to the learners. The learners may or may not know anything about what the teacher delivers, but must take in all the information with the trust of the source. Below is an excerpt where the teacher shows some acknowledgment of the learners being contributors to knowledge building:

> Be receptive to learners' ideas when they give you their own examples of life and science. That will encourage them to have an interest in science.

The above excerpt shows the importance the teacher attaches to involving the learners in the knowledge generation process in the classroom, by giving the learners a platform to share their ideas. He believes this autonomy will stimulate learner interest in science.

How learners learn science: Mr. Charles is of the notion that learners learn science better through experimental work. He emphasized the importance of experimental work when he indicated that teaching of science is better with investigations. He narrated the challenges of the unavailability of apparatus/equipment for experiments, which is an indication that experiment is important to him, thus when available he could have made use of the materials. He believes learners need guidance, there should be a guide by their side for them to learn science. He describes a teacher as guiding the learners through the lesson.

The learners' role in the science classroom: Mr. Charles described the role of learners as being active participants in the lesson. He further described active participation as asking and responding to questions, manipulation of apparatus and data collection, mathematical computations and problem-solving. This is underlined in the excerpt below:

> They should be an active participant for them to interiorize what they have to learn, so active participant means, when you are developing a concept, they must be able to query or to seek a clarification around that. If you pose a question they must be able to give a reasonable scientific answer. If it is experiment, they must be able to manipulate the apparatus and come up with results. If it is solving a problem that includes mathematics, they must be able to do that.

He noted the role of learners in the classroom is dictated by the role of the teacher. Mr. Charles explained:

> There are instances where they have to be listeners, and you give them the instructions or guide them. There are instances where they have to interact with you and then there have to be instances where they must write things down and finally instances where they have to answer assessment tasks.

The excerpt above shows that one other role of learners as perceived by Mr. Charles is being attentive listeners and taking notes. Mr. Charles mentioned learner roles that are associated with a certain teaching orientation. Being attentive and taking notes depict the teacher as a transmitter of scientific knowledge. He mentioned manipulation of apparatus and data collection, which is part of experimental work.

The teacher's role in the science classroom: Mr. Charles acknowledges that he does not have a single role in the classroom; he actually has multiple roles. He explained: "Besides being a tutor, you are a parent, there could be issues of discipline that you could attend to and you could even be a model". He has what he called "normal teacher" roles and "science teacher" roles. The science teacher's roles are to guide learners through the lesson and act as a resource person for the learners. He explained:

> Teachers' roles in a science lesson are multiple, but the most important ones are to guide learners through the lesson and act as a resource person in the lesson. You are acting as a source of information and you can have other normal roles of a teacher.

He also noted that his role in class may shift as the lesson proceeds. He stressed the importance of continual learning for teachers.

4.3.1.3 Mr. Charles vignette

In order to exemplify and triangulate some of the findings depicted above, Mr. Charles was observed teaching Physical Sciences. This lesson was observed during the stock-taking step, before the goal-setting meeting, and was his first lesson to be observed by the researcher. The lesson served as a basis to gauge the teacher's grasp of the concept of inquiry teaching. The lesson was analysed using the inquiry lesson observation tool EQUIP (Appendix F) that was employed as a tool to gauge the extent of inquiry teaching that takes place in a given classroom.

Lesson 1: Conservation of Linear Momentum (Grade 12)

Mr. Charles is a very confident individual who has the most experience of the three teachers under study. He is teaching Physical Sciences and Natural Sciences at the school. At the time of the study he had a learner teacher observing him teach, and in this particular lesson he wanted to teach the concept of conservation of linear momentum. He started his lesson by asking learners to define the term momentum. His main objective was to prove that the total linear momentum of a system is conserved. He told the learners he was going to demonstrate this by using an explosion. He asked the learners to calculate the linear momentum of the system at the beginning. The learners were not able to perform any meaningful calculations.

The teacher had to explain to them how to calculate the linear momentum of the system. The excerpt below shows the teacher interaction with the learners as he explains the concept:

> T: By now you know the formula of linear momentum (p=mv). The two trolleys are 600g each and when they are connected the way you see them, what is their total mass?
>
> L: 1200g
>
> T: By the way something is wrong? Can someone help me with what is not right with that answer?
>
> L2: The mass must always be in kilograms.

T: Yes

The teacher proceeded to show the learners how to calculate the linear momentum of the system at rest. The teacher found that his answer was zero and wanted the learners to explain why his answer was a zero. The majority of the learners could not figure out that the system was at rest and thus velocity was zero. They were convinced they had multiplied by zero therefore the answer was going to be zero. The teacher went on to demonstrate the explosion and two learners assisted with the recording of data. He used the values to perform calculations and finally came to a conclusion that the linear momentum of each of the two trolleys was equal and opposite. The teacher wanted his learner to find reasons for these results, but the learners could only figure out that the trolleys were moving in opposite directions therefore their momentum must have different signs. The learners could not come up with the reason why the magnitude of the momentum was equal. The teacher further explained to the learners the reasons. The excerpt below is the teacher's explanation:

> T: Momentum is the product of its mass and velocity and velocity is a vector. It means when the trolleys are accelerating in different directions and have the same mass and velocity, the linear momentum is equal and opposite. Therefore the sum of the two will give us a zero, thus we have proved that the total linear momentum before is equal to the total linear momentum after the explosion.

The teacher asked the learners to copy into their exercise books the calculations from the chalkboard. The first lesson was teacher-centred, in which the teacher preferred to explain things out instead of further probing for answers. The lesson was further analysed using the inquiry lesson observation tool, EQUIP, which was employed as a tool to gauge the extent of inquiry teaching that takes place in a given classroom. The tool has four basic categories: instructional factors, Discourse factors, Assessment factors, and Curriculum factors. The summative overview on the tool provides the mean score on the level of inquiry demonstrated by the different constructs under each category, sliding on a Likert scale from 1 to 4. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 4.2 Scale statistics for lesson 1 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.0	.00
Classroom discourse	1.2	.40
Assessment	1.2	.40
Curriculum	2.25	.83

The table above shows the average inquiry instruction score of 1.66 out of four on all the four categories. The overall score is the *pre-inquiry* stage, which is level one on the EQUIP four levels of inquiry. This lesson did not show any signs of inquiry on all categories.

4.3.1.4 Interpreting pedagogical orientation from POSTT-PS results and interview

Mr. Charles presents science as a known product and believes good teaching is about making learners understand science content. Thus direct (traditional) methods of teaching are more appropriate to him. There are two variants (didactic direct and active direct) of this mode of teaching in terms of the continuum highlighted before. Of the two variants, he is seen to be inclined towards active direct. He does not want to do everything for them, but understands his critical role in supporting learning.

With this in mind, Mr. Charles thinks didactic direct does not engage learners fully and using the method may be viewed as 'doing everything for the learners'. Despite this view, ten percent of his responses to POSTT-PS in this category may mean that there are times that the method may be utilized in his teaching of Physical Sciences. When asked for the reasons why he selected the response in didactic direct, Mr. Charles indicated that he may use didactic direct when teaching concepts that are difficult for learners.

Mr. Charles is exhibiting the notion that the difficult concepts may be taught through didactic direct. He claims "this approach makes the pathway to understanding smooth for the learners”. In contrast, literature has shown instances where teachers thought that didactic direct is for easy concepts.

Mr. Charles has 10% of his responses as didactic direct. This means only one of the ten responses that he gave was didactic direct. He looks at the abilities of the learners concerned in relation to the level of difficulty of the concepts to be taught. He is then of the notion that whenever the learner ability is lower and the level of difficulty of the concept is higher, he has to use didactic direct strategies. According to him, when the learners are of less ability than required by the activity, then the activity becomes difficult for the learners and then didactic direct will be more appropriate. In justifying his choice in the excerpt above he seems to associate grade 10 learners with certain abilities and thus certain methods of teaching. He associated the teaching of difficult content with didactic direct. When asked to what extent he managed to implement inquiry, the following was his response:

> If you talk of inquiry when learners are in grade 12 and you started in grade 10. Yes, you can tell that you have been somewhere. But at grade ten they are still struggling to find out; what the teacher wants us to do. After a year in grade 11, they start to see the light. In grade 12 I tell you the grade 12 that we have now, they know their business. It takes time, it’s not a once-off thing then you get results.

The assumption in the excerpt above is that inquiry-based instruction needs the teacher to support learners and with time learners will acquire the necessary skills required to successfully navigate through inquiry-based lessons. The less experienced learners have potential to progress with the assistance of the teacher to levels where they could easily navigate inquiry-based instruction.

When asked why he did not choose didactic direct in the other 90% of his responses, he alluded to the wrong sequencing of the steps in a lesson. According to him, exploration must precede explanation. He strongly believes learners must perform an experiment first, after which the teacher can explain a concept to the learners. Didactic direct generally has no practical activities: a teacher presents and explains the science concept or principle directly to learners and illustrates with examples and/demonstrations. The other problem he has with didactic direct is that learners are passive, while the teacher is active. He highlighted that there was too much guidance in didactic direct. In one of his responses, he had this to say: “You are guiding the learner, that’s too much. You would have done this a long time ago. This one is too straightforward”.

Mr. Charles acknowledges the need for guidance, but there must be a balance between guidance and learner input in an investigation. The other interesting feature he raises is his belief that an experiment comes after the theory lesson, thus the learners already know something about what you are about to do. Mr. Charles seems to be saying he can use didactic direct strategies when the learners are quite new to the concept taught and when the content addressed is difficult for the learners to understand. He will not use didactic direct for the topics that are familiar to learners and for content learners find easy to understand. Mr. Charles has a bias towards non-inquiry methods of teaching but does not believe in the teacher doing everything for the learners, thus in most cases he is left with the active direct as his most preferred method of teaching.

In the POSTT-PS, 50% of his responses fall in the active direct orientation, which means five out of ten responses were active direct. His reasons for choosing active direct strategies of teaching are based on four things: the level of difficulty of content, type of activity, type of learners and sequencing of content. He associated ‘familiar content’ with more learner-centred strategies of teaching. Familiar content, in this case, will be a topic or concept that learners already know. In one of his responses to justify selecting an active direct response:

> Learners in this grade might know the thermometer from the hospital and asking them questions might provoke the appropriate thinking around the apparatus. From their responses, I am able to lead the learners to a conclusion on the structure, use and building of the model of a thermometer.

Mr. Charles believes a good teaching method should take into account the learners’ previous knowledge. When certain that the learners have some background knowledge of the concept, he would consider active direct strategies.

When asked to give examples of cases where active direct strategies are not appropriate, he alluded to the wrong sequencing of steps during the lesson, especially the exploration and explanation. He finds a problem in giving the learners the law first and then asking them to conduct an investigation that aims to verify the law. In some cases he finds active direct to have some degree of autonomy he feels is not appropriate, especially at lower grades. He would emphasize the use of worksheet rather than notebook when learners are recording results from an experiment. He actually prefers learners to complete a table than to have learners generate their own table of results (decide on the variables and construct their own table). He may allow the senior grade such as grade 12 to record the data in their own format as he believes they now understand the dependent and independent variables. He is also sometimes not happy with the level of guidance that comes with active direct. He felt that there was also too much guidance in active direct strategies. One of his responses:

> This one, you have guided them too much again. Tell them about the law some lessons before and do the experiment separately. Then they can think which one does fit.

Mr. Charles acknowledges the need for the teacher to refrain from transmission. In as much as he believes learners must be given an explanation or handouts with the method beforehand, he is against too much guidance during the practical. Mr. Charles feels too much guidance stifles learner participation in an investigation. The other interesting feature he is raising is his strong belief that an experiment comes after the theory lesson, thus the learners are not new to the concepts, thus do not need as much guidance. Mr. Charles seems to be saying he can use active direct strategies when the learners are either familiar to the concept taught or find it easy to understand. Mr. Charles showed a tendency to associate active direct with more senior and experienced learners and didactic direct with junior and less experienced learners.

With 50% of his responses falling in the active direct and 10% in the didactic direct, it therefore means 60% of his responses fall in the non-inquiry orientation and only

40% of his responses are inquiry. Even if 60% of his responses are non-inquiry, he does not totally disregard inquiry practices.

He has some regard for inquiry practices that give guidance to the learners. When asked about the benefits of inquiry in an interview, he mentioned four types of learner benefits used in literature to justify inquiry choices: learner responsibility, active thinking, affective benefits and content-specific learning outcomes. The following excerpt was his response to the benefits of inquiry-based teaching:

> It develops a sense of independence in the learner, critical thinking; it inspires confidence in the learners because they are actually doing the work themselves, it develops responsibility in the learner, it has a very good effect on teamwork and collaboration. It also sharpens the aspects of ability to research on the part of learners.

Mr. Charles is informed about the benefits of inquiry, although he does not have an adequate understanding of the term inquiry-based teaching as learned from his definition of inquiry in the first interview. When asked if he could use guided inquiry, he indicated that he would use the method for some experiments. To him, this method works better with higher grades. He is the only teacher participant in this study with less than 50% of responses in inquiry. In the POSTT-PS, only 40% of his responses were inquiry. An interesting observation is that all of his inquiry responses are in the guided inquiry orientation. His reasons for choosing guided inquiry were much focused on the lesson format (moving from the known to the unknown), linking science and the learner’s environment and removing misconceptions. When teaching Newton’s laws, for instance, he finds it easier to use guided inquiry because the topic is treated in the senior grade and is based on what he called real-life situations. In an extract from his reasons for choosing guided inquiry:

> Raising a question for this topic would provide answers from learners that are practical. Newton’s laws are based on real-life situations and understanding relationships would not be complicated or too abstract. The mathematical relationships would be better understood when learners are provided a chance to verify the law experimentally.

This relates well to the trend that he has shown from the beginning, that the more familiarity with the content or activity, the more he is willing to reduce teacher control. This also applies to the grade level in that the higher the grade (abilities of learners), the more learner responsibility/autonomy he is willing to give.

Mr. Charles selected responses that gave the procedure to follow for most of the items that depict an experiment in the POSTT-PS instrument. In the follow-up to the POSTT-PS interview he indicated that he feels it will be challenging for his learners to come up with their own method. The CAPS document explained, an experiment will refer to a set of outlined instructions for learners to follow in order to obtain results to verify established theory. When asked to explain why he prefers to give a method in a practical investigation, he explained: "Nowadays, for example in CAPS, when you say practical investigation that is when you need the learners to come up with their own method, but if it's an experiment you must provide learners with that." He further explained that even when it's an experiment, no marks are allocated to the method. It can be inferred that Mr. Charles's practice is influenced by the assessment methods. He disputes the use of guided inquiry for the lower grades, for example grade 10, which he considered less skilled and less prepared. He is also of the notion that guided inquiry is rather too difficult for the learners. He strongly feels learners need to be guided on some aspects of the experiments, such as what particular aspects of the experiment to observe.

Mr. Charles did not choose any response in the open inquiry orientation. When asked to respond in the interview he consistently showed a negative view of open inquiry. His responses indicate a deep sense of scepticism regarding the use of open inquiry to teach science. He is sceptical about his learners' ability to work on their own. He regards open inquiry as too difficult for the learners and believes it is meant for higher-order learners:

> It is so open, the learners work independently. They do their own method. They experiment on their own, write up results and conclusion. This one is a high-order practical which would need learners in higher grades than grade 8. Somehow you must check and balance the work that they are doing. You leave learners to their own

> devices – it’s too open. It’s like you are talking of a university learner, not high school learner.

He did not choose any responses in open inquiry, thus did not give any reasons for open inquiry. All his reasons were against the open inquiry strategies. An excerpt below highlights some of his reasons for not choosing open inquiry as a method of teaching:

> I think this one does not work. For them to say, for today we want to do this, it would mean to me that learners know what they are going to do. Then it defeats the purpose of education.

Mr. Charles sees open inquiry as an insurmountable task for the learners whom he views as not having the required skills to do their own full inquiry, especially when practical work is concerned. According to him, the only way it can work is when the teacher leads the way by doing a similar investigation then the learners can use that as an example to come up with their own. This is what he had to say concerning this:

> They can do their own research and then they can do it provided you first did something on that. For example, you do an experiment on how you measure the rate of reaction. Then you can say, can you design yours to measure any rate of reaction? And then they can pick the factor that they want for example temperature. Even though here you will be talking to learners who have a high cognitive level of ability.

Mr. Charles thinks his learners are not ready to design an experiment. He further explained this in terms of lack of experience and expertise of learners at doing inquiry. He feels learners who are from low-income communities are less exposed to the concept than their counterparts in high-income communities:

> We are having learners who are coming mostly from informal settlements and their exposure to the world of science or the general world is not as wide as somebody who is in a better economic environment.

According to him, open inquiry demands a lot of scarce skills such as coming up with an investigative question, identifying the independent, dependent and control variables. He believes these skills may need a lot of time to develop. He mentions the issue of time frames and how much you can achieve in that time. Mr. Charles believes learners need to be directed so that they focus on things that are important. He explained:

> In a practical investigation, a lot of things can happen and a learner can tell you things were like this, which was not the focal point of the practical. So you sort of blinker them or focus them on the issues they must watch out for. Learners can explore and give you strange and interesting things, but time is not on our side. Just saying do as you wish and come up with the results is not good for any grade. Learners are going in circles and there is no time for that.

Mr. Charles acknowledges the great potential in learner explorations, but he is not convinced he has enough time. He does not see any efficient use of time in implementing open-inquiry strategies. The issue of time constraints, coupled with the realities of his classroom, work against the use of open inquiry. Mr. Charles believes his learners may not possess the required knowledge and investigative skills from the lower grades. This is one other factor that is a deterrent to him choosing open inquiry approaches to teaching science. These could be the reflections of a teacher who thinks transmission works best for him and does not seem to be willing to try new things.

Here we see a teacher is in total agreement with the inquiry approaches from the epistemological point of view, but in disagreement from the practical side of things. Having considered the contextual factors and the learner abilities, he is already convinced that open inquiry is not a possible option in his teaching.

Summary of Mr. Charles‘s orientation to science teaching: Mr. Charles's orientation was informed by his experiences as a learner and teacher. First, he still has memories of his high school science teacher and what he used to say about science, some of which is inherent in what he is also saying to his learners. This experience as a high school learner encouraged an interest in teaching science and scientific literacy. He explained:

> I think what made me end up being a teacher is the interest probably instilled in me by my science teacher. I can't say there was much of inquiry in what he was doing, but what he was doing instilled in me what I can call the world of science. He used to say, if you can talk science at home or anywhere then you have understood science. Let's take an example of beer: if someone drinks beer and tomorrow they have a hangover, if they can explain that in terms of science then they have learned science. I can still remember much of the practical and the notes he gave us. His approach was more directed: do this, do this. When we came to the conclusion of an experimental write-up, that's when they would want to find out, what do you think- that has been there till today. The majority of the content he had to deliver is as it is.

Mr. Charles's high school teacher had an important influence on his beliefs about teaching, learners and learning. As well as his practice as a Physical Sciences teacher, he highlighted the fact that he was an A-learner and a teaching method that could have produced his good results at the high school may appeal more to him than any other. Second, his early experiences as a teacher, teaching high school science, may have influenced his views on teaching, learning and learners. This could have informed his goals and purposes of teaching science as well as his perception of learner and teacher roles. Mr. Charles described his school and community as economically depressed. The lack of facilities made experiment difficult. Observations of Mr. Charles teaching on Day 1 indicated greater reliance upon direct methods rather than inquiry instructional sequences. His responses to POSTT-PS are such that 60% of the responses are non-inquiry while 40% are inquiry. Mr. Charles's orientation to teaching science would be best described as active direct.

4.3.2 Profile of Mr. Kapok

Mr. Kapok's profile is presented in this section in terms of his teaching background and beliefs. These were extracted from qualitative data from analysis of interview transcripts. The analysis of quantitative data from the EQUIP for the first classroom observation culminates in Mr. Kapok's vignette. Lastly there is interpretation of Mr. Kapok's pedagogical orientation as depicted by the results from the POSTT-PS and a follow-up interview.

4.3.2.1 Teaching background

Mr. Kapok has been teaching science for the past three years at Rahuni High School. He has not worked in any other field but teaching. He graduated from a South African university with a Bachelor of Education. Mr. Kapok loves his job and he knows his learners very well. He explained: “I like teaching. I don’t do teaching for the money. If you can see when I am teaching the 12D learners, teaching becomes interesting”. He did not enjoy his experiences as a learner at high school; he is convinced his high school was dysfunctional. Some teachers were not honouring their periods. The only thing he liked about the school was his science teacher. He regards him as a good teacher. He went to a university where all his science lecturers were good. Mr. Kapok is teaching Physical Sciences at a township school on the eastern side of Gauteng province. The school has an enrolment of 1352 Learners. He is teaching Physical Sciences (grades 10-12) and Natural Sciences (grade 9). He is at a school that has been identified as non-performing or priority school. A priority school is a school that has consistently failed to produce good results for the previous three to five years.

His Physical Sciences classes have an average of 40 learners, and this is above the learner-teacher ratio of 1/30 for the department of education. Mr. Kapok’s teaching space consists of a traditional laboratory with two rows of tables (work benches) with laboratory sinks and boards fitted at the back of the room.

The laboratory has five work benches in a row, thus a total of ten working stations, sinks with running water and electricity. Mr. Kapok shares the laboratory with another Physical Sciences teacher, but he is free to use the laboratory whenever he wants. In front of the learners' workbenches are the teacher's desk and chalkboard. On the teacher’s desk are a laptop and a data projector.

4.3.2.2 Teaching beliefs

Mr. Kapok's teaching beliefs are described by addressing aspects of his instructional practice in terms of (a) the value of science and science teaching; (b) the nature of science and goals of science instruction; (c) control in the science classroom; (d) how learners learn science; (e) the learner's role in science classroom; and (f) the teacher's role in the science classroom.

The value of science and science teaching: Mr. Kapok indicated his ideal lesson must start with a demonstration by the teacher or an experiment by the learners. The learners will make observations and record results in both cases. The learners then respond to the teacher questions on the demonstration or experiment. The teacher gathers all the learners' contributions on the chalkboard and discusses them with the learners. Learners then come up with a conclusion they have reached from the discussion. The teacher will then explain the whole concept as he summarises the lesson. In all this, the teacher is trying to provide learning experiences that encourage thinking and learner participation. Mr. Kapok's image of teaching Physical Sciences was influenced partly by his experiences in high school and university. He noted that both his primary and high school teachers were engaging them in experiments. He explained:

> My science teacher was good: we were doing experiments at school. There was no way you could say you did not understand physical science because he was always there at school for us and you could ask questions when you wanted to ask. If I can be a teacher like that teacher, then it will be good for learners because that one changes the life of learners.

When performing experiments, Mr. Kapok believes learners must be given clear instructions about how to carry out the experiment. He does not believe in learners coming up with their own method as he has learned that in most cases learners struggle with identifying the variables, especially the control variable. He indicated that if the learner does not know which variables are kept constant, the results are meaningless. He explained:

> When you do those experiments there are variables that must be kept constant. There are only two variables that must change. The other variables must be constant. If there is no instruction sheet, the other variables may not be kept constant because these learners may keep on changing them. For example, let us say the mass of the substance was supposed to keep constant; they may keep on changing the mass because there are no instructions saying keep the mass of the granules constant.

Mr. Kapok strongly believes the objectives of an experiment must be clearly defined, and expectations for learners clearly laid out. He thinks learner participation is a critical factor in the teaching of science and ensuring learners understand what is expected of them in an experiment is of great importance. Mr. Kapok's ideal image of teaching is through learner-centred strategies, but he noted that time is often his major drawback.

The nature of science and goals of science instruction: Mr. Kapok believes science is meant for learners to develop critical thinking skills. He admits it is unfortunate that the teaching of science is still through the traditional transmission method. He explained: "Us science teachers, we are not teaching science the way it is supposed to be taught because science is supposed to be taught through discovery, not telling method". His first goal is to prepare learners for college or the workplace. He explained:

> What is happening in school is actually the total opposite of university, that's why with the level sevens they still drop out of the university. That's why they say at university there is no teaching, they just give you textbooks. No, they are teaching, but they are not using the telling method. Remember this thing of the experiment does not end here at school; these learners are going to be engineers. They will go to companies and there will be problems there at the companies. They must be able to see those problems and solve them.

The second goal for teaching science for him is to develop in the learners thinking skills. He explained: "Science learners must be critical thinkers". His third goal is to make the learners understand Physical Sciences. He supports learners to construct their knowledge of Physical Sciences. He believes the exploration comes before the explanation, with the teacher acting as a facilitator while the learner is an active participant. Mr. Kapok wants his learners to participate in coming up with concepts and does not want to do it for them. He discouraged teaching methods that give everything.

Control in the science classroom: Mr. Kapok believes science is about critical thinking. He explained: “Once you spoon-feed them it’s no longer a science because they are not thinking. Science is about critical thinking.” He further explains that science is a discipline that encourages the discovery method. Mr. Kapok does not believe in methods of teaching that give learners all the information. He believes there must be a difference between the teaching of science and the teaching of other subjects. In contrast, when observed in class the first day he had control over the activities in the classroom. One could have expected him to be learner-centred in the way he presents science. The fact that he was teacher-centred may suggest the presence of other factors that affect his choice of teaching strategies.

How learners learn science: Mr. Kapok believes learners must be allowed to first try things on their own in science class. He is against doing things for the learners and recommends learners' participation, with guidance from the teacher. Teacher guidance must come in after the learners have been given an opportunity to explore. Mr. Kapok has regard for learner-centred methods of teaching and views a teacher as a facilitator. According to him, the learners must be given a chance to explore, discover things on their own and ask questions. It is unfortunate that his views did not match his actual classroom practice. When observed in class the first day, he used direct methods of teaching, without any exploration.

***The learner’s role in the science classroom*:** Mr. Kapok described the role of learners as being prepared to search for information on their own. He explained this role as being able to read their textbooks and get information. He explained: “They need to read those books so that they can have information before you teach them. It’s easy to teach learners who already have some information, than blank learners”. The learners must respond to the teachers’ question. He explained: “Instead of explaining how it works you would rather ask them how it works. Therefore they respond and after they respond to your question, then explain how it works”. He believes asking questions will make learners think and avoid being passive in class. Thinking and observation in his view are the major roles for a learner in his lesson. The learners will use evidence from their observations to generate explanations.

The teacher's role in the science classroom: Mr. Kapok believes a teacher must design lessons that challenge learners to think. In addition, the teacher must motivate learners to learn and be as inclusive as possible. He finds keeping them motivated a key aspect of his role as a teacher. He explained: "They need motivation from us. You don't just teach, teach without motivating these learners". Mr. Kapok believes he is not just in class to teach Physical Sciences concepts but to build a wholesome learner. He further explained the need to give career guidance to his learners. He explained:

> Some of them, they just do Physical Sciences; they don't know what they are doing it for. You ask them, why are you doing physical science? They say it has many job opportunities. What are those job opportunities? It's a problem. Even me, when I was schooling in high school, I knew nothing about university, careers, I was just passing science. As long as there were calculations, I was just calculating.

He is driven by his own unpleasant experiences as a high school learner when he did not receive any career guidance. One other role of the teacher Mr. Kapok perceived as important is assessment. He believes regular assessments are good for learners and teachers. He believes marking learner scripts allows the teacher to discover some of his misconceptions. He explained:

> Teaching without assessment is not good. When you teach and assess, you can quickly identify misconceptions. I also have misconceptions, but when I am marking I see on the memo that this one, it's me who taught this. I go back and do corrections and correct that misconception. Some learners fail not because they don't know, but they apply the wrong information that we taught them.

The assessment also gives good feedback from the learners that may be useful in shaping current and future lessons.

4.3.2.3 Mr. Kapok vignette

Lesson 1: Resistors in series and parallel (grade 10)

This lesson served as a basis for a baseline assessment to gauge the teachers' concept of teaching using the inquiry method. Mr. Kapok is teaching series and parallel connection of resistors to a grade 10 class. The lesson took place in the stock-taking step of the study and was the first lesson observation for the teacher. The lesson was on electric circuits and the teacher wanted the learners to establish the difference between resistors in series and resistors connected in parallel in terms of current and voltage. The teacher started by greeting the learners and asking them to go into their usual groups. He had already placed on the tables pages with diagrams of electric circuits. The class had forty learners divided into eight groups. The learners were eager to learn and they had their notebooks. The teacher started the lesson by assessing learner prior knowledge. The following excerpt is the evidence of the interaction between the teacher and the learners:

> T: How many bulbs are there in circuit A?
>
> L: One
>
> T: What is the difference between circuit B and circuit C?
>
> L: In circuit B the bulbs are connected in series and in circuit C the bulbs are connected in parallel, responded the learners.

The learners were seated in their groups, but were never given a chance to discuss anything; rather, he asked them questions about the circuit diagrams. When he realized that the learners knew the parallel and series connection, he then proceeded to calculations. Mr. Kapok indicated in the post-lesson interview that when he realized the learners understood the difference between the parallel and series connection, he had to proceed to mathematical computations. Mr. Kapok made use of diagrams on the chalkboard to discuss important differences between the parallel and series connections. Mr. Kapok decided to give the explanation before the mathematical computations, as explained below.

T: Let me start with series. Now we are going to calculate the total resistance of the circuits. The total resistance of the resistors connected in series is not the same as the total resistance of the resistors connected in parallel.

Mr. Kapok wrote the formula of calculating the resistance of the resistors in series and asked the learners to calculate the resistance. There was talking as the learners shared ideas and attempted the question. Mr. Kapok walked around the class and came back to the chalkboard. He led the class in the mathematical computations on the chalkboard. After getting the answer, Mr. Kapok asked the learners the calculation of the resistance of the resistors in parallel connection using the given formula. There was some noise as the learners tried to figure out the calculation. The teacher moved around and checked their calculation. The following excerpt demonstrates how the teacher engaged the learners as he went around the groups to assess the progress and possibly offer assistance:

T: We now have the total resistance of parallel and total resistance of the series connection. What do you notice about R-parallel and R-series?

[*The group remained quiet. He started to explain*.]

T: look at the resistors in series, the total resistance is 5 ohms and the two resistors are 2 and 3 ohms. Look at the total resistance of the resistors in parallel: It's 1, 2 ohms which are smaller than both resistors. It means if resistors are in series connection the total resistance is more than their individual resistances and in parallel the total resistance is smaller than any of the resistors. If you want to increase the resistance of the resistors, do you connect them in parallel or in series?"

L1: We connect them in series.

T: When you want to increase the resistance of the resistors you connect them in series and when you want to decrease the resistance of the resistors you connect them parallel.

The teacher also used analogy to explain concepts. The excerpt below is the evidence of the use of metaphor to explain science concepts.

> T: Guys, the greater the resistance, the lower the current. The smaller the resistance, the greater the current. Are we all together. When you think about the speed humps in the road, if we look at the car as the current, the humps affect the speed of the car. If the speed hump is too big, it means the car won't pass. The same with current - if the resistor is too big the current won't pass. That's why we connect the voltmeter in parallel, because it has high resistance and current won't pass through if it's in series.

There were also moments when teacher and learners interacted with each other, especially when the teacher asked open-ended questions:

> T: The greater the resistance, the lower the current. The smaller the resistance, the higher the current. From the two circuits we looked at today. Which one has a higher current?
>
> L1: The circuit with resistors in series.
>
> L2: The circuit with resistors in parallel.
>
> T: Why do you say it's the circuit with resistors in parallel?
>
> L2: The circuit with resistors in parallel has smaller resistance, thus more current.
>
> T: That's correct, also resistors that are connected in series have the same current. If you know the current of one of the resistors then you know the current of all, but with the resistors connected in parallel the current divides. Unless the resistors are the same, their current is going to be different. In this case they are different.

The lesson is largely teacher dominated, although there were moments of teacher-to-learner interaction and learner-to-learner interaction. The teacher was not patient enough to probe learners deep to extract answers from them, but chose to give them the required content as he proceeded. The teacher had an activity in mind that would engage the learners.

He started his lesson well, with questions that could test the learners' prior knowledge on electricity, especially electric circuits. The learners could respond to questions well, although the questions in the majority were closed questions. The teacher asked open-ended questions, especially at the end of the lesson where learners needed to explain and justify their answers. The learners were not given an opportunity to explore by performing relevant practical investigations. An opportunity was missed where learners were supposed to set up a circuit and record the voltage and current on their own. The EQUIP inquiry classroom observation tool was employed to measure extent of inquiry teaching that took place in this lesson. The tool has four basic categories: instructional factors, discourse factors, assessment factors and curriculum factors. The tool provides the mean score on the level of inquiry demonstrated by the different constructs under each category, sliding on a Likert scale from 1 to 4, each category was then scored according to the following Table 4.3, on the level of inquiry it represented.

Table 4.3 Scale statistics for lesson 1 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.0	.63
Classroom discourse	2.6	.49
Assessment	2.4	.49
Curriculum	2.3	.47

The table above shows the average inquiry instruction score of 2.33 out of four on all the four categories. The EQUIP has four categories and each category was scored out of four. The total score for the categories was then divided by four to come up with the mean overall score. The overall score is *developing inquiry* stage, which is level two on the EQUIP four levels of inquiry. This lesson was teacher-centred but did show some signs of inquiry on classroom discourse. The teacher occasionally acted as a facilitator, but it was for brief moments.

4.3.2.4 Interpreting pedagogical orientation from POSTT-PS results and interview

10% of Mr. Kapok's responses to POSTT-PS were in the didactic direct orientation while 30% of his responses were in the active direct orientation, thus 40% of his responses fall in the non-inquiry orientation; 40% of his responses to POSTT-PS were guided inquiry and 20% were open inquiry. In total, 60% of Mr. Kapok's responses were inquiry. An interesting observation is that only 10% of his responses were in the didactic direct orientation. This may mean he did not see many of the responses in the didactic direct as appropriate. In his response to the question (interview 1), why he did not choose didactic direct, this is what he said:

> I left this because all the work is done by the teacher. Nowadays the work must be done by learners, they should discover first and therefore the teacher must facilitate. They must do this after they have done some discovery, that's why I left this one. Actually, this one is teacher-centred it's not learner-centred. Learners must discover themselves. They ask the question, you give them direction after they have discovered themselves. It's teacher-centred. The learners should be the ones who work …learners are not discovering things for themselves, actually they are listening, they are just listening and they are writing notes and after that, they go home. So they come to listen, that's what I hate.

Mr. Kapok's espoused beliefs were against teacher-centred methods of teaching. He explained: "In this method, the teacher does all the work when the work must be done by the learners". Mr. Kapok preferred a method of teaching that was learner-centred. He considered didactic direct as a teacher-centred method and he thinks the teaching of science must be learner-centred. According to him the policy statement on the teaching and learning of Physical Sciences (CAPS document) encourages active learning. He explained: "The CAPS document encourages learners to be active participants in class".

Table 4.1 shows that 30% of his responses fell in the active direct orientation. This was very likely because of one of Mr. Kapok's indicators of good science teaching were learners doing the work. In active direct we see learners engaged in hands-on activities that may not necessarily be minds-on. He made mention of the demands of the department of education through its curriculum documents influencing his choice of a teaching method. He explained: "We are required to provide a written method for experiment up to grade 11 and only grade 12 can be asked to design an experiment". This may explain why approaches that give a method to the learners are still appealing to the teacher and more so if it is accompanied by learner activity. Besides the department requirements, Mr. Kapok believes learners need clear instructions whenever they are given a task. What the teacher has ruled out is teaching approaches that are highly teacher dominated.

When explaining why he did not choose active direct responses 70% of the time, he explained:

> The teacher already gave them the answer, whereas they should come up with the answers. In science we need some discovery, learners must be active and they must work. As a teacher you must facilitate, you must give them direction after they have discovered something. They are not going to be a statue. Some learners are passive, very passive, they don't do things for themselves - they rely mostly on teachers. They don't work, that is why we are crediting this thing of self-discovery.

He highlighted the fact that there isn't much difference between didactic direct and active direct. He explained: "The teacher is still seen to be doing much of the work instead of letting the learners do it". He further explained that active direct lack self-discovery. The need for learners to discover something may account for the higher percentage of his responses being in the inquiry orientation.

When motivating why he selected guided inquiry as an option, Mr. Kapok indicated "the method enforces learners to participate actively and discover things themselves. The teacher gives assistance and learners can come up with authentic conclusions. The approach has a positive effect on learners to think critically and explore". When looking at the way the teacher expressed himself in interviews, this is one approach I expected him to have in the majority of his responses. It only turned out to be 40% of his responses, almost the same percentage as his responses for active direct. One of the contributing factors could be the issue of not giving the learners the method. Although the approach acknowledges the need for guidance, it did not provide the method. In a follow-up interview to POSTT-PS he explained: "I won't be free to have my learners do an experiment without a method, because sometimes you may think that the learners may perform the experiment but may end up doing something you do not want".

When responding to the question, why he did not select some guided inquiry responses:

> It's difficult for learners because in an experiment according to CAPS the teacher provides a method. If the teacher did not provide the method, it may be chaotic to say to learners, this is the apparatus so do something. Someone may be injured because sometimes we use chemicals such as sulphuric acid. We are talking about learners in high school, not learners in tertiary. Actually, there must be a method which instructs them. They will do everything, like coming up with the aim and conclusion. Grade 12, you just give them the method but in the report they should summarise that method.

The teacher raised issues of safety, which is an important concern identified by other participants as well. He believes learners have difficulties when doing an experiment without laid-down procedure. I think what may be difficult would be the teacher support that goes with that. This means raising their level of awareness if they are working with harmful substances. That preparation of the learners and the environment may be what the teacher sees as impossible, if not time-consuming. The teacher has no confidence that his learners have the necessary skill required to fulfil the demands of independent explorations. The most surprising part of this is that Mr. Kapok opted for responses from the open inquiry orientation.

Mr. Kapok had 20% of his responses from open inquiry orientation. The excerpts from his motivations on the POSTT-PS instruments show that he greatly regards this teaching approach. He thinks open inquiry gives learners autonomy as they discover things on their own. The method gives the learners an opportunity to investigate their ideas and revise them before or after the teacher intervenes. He applauded the approach of allowing the teacher to be a facilitator and learners active participants. The teacher is seen in other circumstances scaffolding the learners by referring them to the internet for further research about their findings in class. This is the evidence in the following excerpts from the POSTT-PS:

> It encourages independent learning; critical thinking requires learners to apply scientific knowledge and also contributes to self-discovery. That's what science is all

about. It makes one be aware that science is a reality. We live Science. It also instils exploration where a learner has an opportunity to express him or herself, able to share to others and exchange their discovery. The option encourages teacher facilitation and a learner being an active participant as needed in teaching-learning situations, especially in science. Learners are also advised to go online to discover an explanation about their findings. The approach creates a room for learners to discover by themselves through applying scientific knowledge… correct observation and correct conclusion.

Interestingly, all his responses had nothing to do with classroom contextual factors. The teacher views the teaching and learning from the epistemological point of view (how do we come to know science?) irrespective of our contextual factors. This could be the reason why 60% of his responses were in the inquiry mode of teaching. He acknowledges that open inquiry mirrors what science is all about, a reflection of what scientists do every day. In an effort to understand his perceived limitations of the method, I asked the teacher to give reasons why he did not select all his responses from an open inquiry orientation. He indicated that sometimes the approach is not clear on what the learners are supposed to do.

Summary of Mr. Kapok's orientation to science teaching: Mr. Kapok's orientation was informed much by his experiences as a high school learner and university learner. First, he still has good memories of his high school science teacher as one who can change lives. This experience as a high school learner encouraged an interest in teaching science. Mr. Kapok's high school teacher had an important influence on his beliefs about teaching, learners and learning. Mr. Kapok's orientation towards science teaching would be best described as guided inquiry. First, Mr. Kapok would opt for options that engage learners with explorations of concepts, prior to explanations. Second, Mr. Kapok has regard for methods where learners are actively involved, making observations and coming up with possible explanations. He sees the teacher as a facilitator.

4.3.3 Profile of Mr. Moloku

Mr. Moloku's profile is presented in this section in terms of his teaching background and beliefs. These were extracted from qualitative data from analysis of interview transcripts. The analysis of quantitative data from the EQUIP for the first classroom observation culminates in Mr. Moloku vignette. Lastly, the interpretation of Mr. Moloku's pedagogical orientation, as depicted by the results from the POSTT-PS and a follow-up interview, are presented.

4.3.3.1 Teaching background

Mr. Moloku is a veteran Physical Sciences teacher with more than 20 years of science teaching classroom experience. After graduating from high school, he taught at a rural school for two years, then went to a teachers' training college. He obtained a two-year teaching diploma in science education, although this was not his original plan. He had intended to enrol for Mathematics education at college, but was requested to do science by the institution. He later earned his Bachelors and Masters in science education degrees as a practising teacher. He has memories of his science lecturer at a college of teacher education and still uses some of the lecturer's illustrations today in his classes. He is highly qualified and very confident in his science classes. He was involved with professional development groups as a cluster leader for Physical Sciences.

Mr. Moloku teaches Physical Sciences and Mathematics at Kathy High School. Kathy High is one of the township schools in South Africa. The school has a population of 830 learners, with the majority of them being black. Mr. Moloku's classes consist of between 30 and 35 learners. This is consistent with the learner-teacher ratio of the Department of Education. Mr. Moloku's teaching space consists of a traditional laboratory with two rows of tables (work benches) and laboratory sinks and cupboards fitted at the sides around the room. The laboratory has five working stations with sinks, running water and electricity. Mr. Moloku is the only teacher assigned to this laboratory, thus he uses this facility every day for all his classes. The laboratory consists of two rows of learners' work benches with the chalkboard in front of the room. One laptop is located on Mr. Moloku's desk in front, but there is no data projector. Mr. Moloku has taught Physical Sciences (grades 10-12) at Kathy high school for the past ten years.

4.3.3.2 Teaching beliefs

Mr. Moloku's teaching beliefs are described by addressing aspects of his instructional practice in terms of (a) the value of science and science teaching; (b) the nature of science and goals of science instruction; (c) control in the science classroom; (d) how learners learn science; (e) the learner's role in science classroom; and (f) the teacher's role in the science classroom.

The value of science and science teaching: Mr. Moloku indicated his ideal lesson must provide learning experiences that encourage thinking about the concept at hand. He believes in learners forming a concept with the guidance of the teacher. When asked what he defines as effective teaching, this was his response: "Teaching whereby learners will be able to grasp the scientific concepts and be able to correctly respond to questions that involve the concepts". This image of teaching Physical Sciences may have emerged from his experiences as a college student. He noted that he still uses some of his science lecturer's illustrations in his lessons. He believes there must be learner participation and his interaction with learners gives him important feedback that guides future decision-making. The feedback will help in future planning and measure learner understanding of concepts taught. He explained:

> The question is part of the teaching; it helps to capture their attention and to assess whether what you are saying is getting into their heads. You cannot just continue, maybe they are not getting you, so as you teach here and there you ask them, they respond. Their response will tell you whether to continue or to revisit something so that they understand before you go too far.

Mr. Moloku's ideal image of teaching is through asking questions. He find asking questions as a way of supporting learners in inquiry-based investigations.

The nature of science and goals of science instruction: Mr. Moloku has a strong belief that science classes are meant for teaching learners how to think independently, explore scientific concepts, come up with concepts and apply their knowledge to solve the problem in similar situations. He explained: "Whatever method I choose, I need to use a method that will make the learners think, I want them to be involved mentally, to be minds-on and at the same time hands-on". I identified two overarching goals for his teaching. His first goal is to guide learners to discover scientific concepts or support them as they construct their knowledge of Physical Sciences. When asked the kind of advice he can give a secondary science teacher, he said: "Be a facilitator, a guide, a helper to the learner. Be practical and be prepared fully." Mr. Moloku wants his learners to come up with concepts 'on their own' and does not want his support to diminish their autonomy. His second goal is to encourage critical and scientific thinking. Mr. Moloku wants the learners to think and come up with the concept themselves. He explained: "We are giving learners more information. We are making the learners not think and discover the concept on their own".

Control in the science classroom: Mr. Moloku believed in minimum control in the science classroom. He believes there is need for guidance in the teaching of science, but learners must be given autonomy to design experiments on their own. This suggests that the teacher must have minimal control over the learning process. It is crucial to balance between giving learners suitable guidance and leaving sufficient scope for them to think independently. Mr. Moloku strongly believes in guidance being given to learners during investigations, but this guidance should not reach levels where it may stifle thinking. Mr. Moloku explained: "Learners need minimal guidance that will keep them on their toes." Instead of telling them everything, he would rather ask them questions so that they are engaged or apply their minds. The teacher will make use of the learners' contributions to build a concept. Mr. Moloku believes that investigations are more than confirmatory in nature, thus can also be used to facilitate learning. He is against teacher control and prefers teacher guidance. He seems to believe much in the inquiry mode of teaching.

How learners learn science: When Mr. Moloku was asked to define inquiry, the following was his definition: "I think maybe it will be looking at the learner and then you kind of have questions to find out how much they know from the concept that you want to teach them". Mr. Moloku views inquiry as a teaching strategy that incorporates questions as a way of getting learner prior knowledge. When asked to give an example of a lesson where he used inquiry-based teaching, he gave an example of an experiment he did with learners on intermolecular forces:

> I don't know whether this will be completely inquiry, because like I said now they are doing experiment, not an investigation. The learners were supposed to investigate how the intermolecular forces in different substances affect things like the boiling point, the rate in which they evaporate, their solubility, capillarity, things like that, so the way I did it as I said before the experiment, they went and read from the book. When they come I give them the materials and then now have to carry on the experiment. So when they were supposed to investigate evaporation they took the different samples with them in sunlight. They did their observation on their own and they now identified this one evaporated more than this one. So their task was to say why. They went on their own. They had to do some research and find out so they had to relate intermolecular forces to the rate at which the liquid was evaporating. There was something on the boiling points, when they were heating they found out that acetone boiled first and water boiled at 100°C and glycerine did not even boil at the temperature they were heating at, so the question was to find out why.

Mr. Moloku believes in using investigations when introducing new concepts or topics and when consolidating concepts or ending a topic. When explaining how he uses investigations in his teaching, he says "at times, but not that often to introduce the topic and at times to consolidate that particular concept that you are teaching". The teacher seems to have a belief that investigations are useful for teaching and learning of Physical Sciences, but does not use them often. When explaining how the investigations assist him in the teaching of Physical Sciences, this is what he said:

> To some extent they do help, because if you taught a topic and now they come to do the investigation, the practical part of it, you find that they tend to understand some of the concepts better because they have done them practically hands-on.

An analysis of the excerpt above shows that Mr. Moloku believes practical work augments theory. He perceived learners understand better when experimental work is integrated in the teaching of science. According to him, investigations are not a subset of teaching, which may suggest the teacher has much emphasis on content acquisition. It is important to note that content acquisition is not the only goal of science education. He viewed experimental work as time consuming. The issue of syllabus coverage is seen to be influencing some of his classroom decisions.

***The learner's role in the science classroom*:** Mr. Moloku described the role of learners as being prepared to come up with/discover new concepts. He further described learners' roles as being prepared to apply knowledge to solve unique problems in novel situations. Mr. Moloku believes learners need to design the method themselves. He believes this will make learners think and take ownership of the work. He explained:

> When they arrive at a conclusion on their own, I am sure they would have understood the whole concept that will be involved to that particular aspect and it helps them to have the sense of ownership to that knowledge. That I have discovered this and it will stick in their minds.

Thinking is the major role of a learner in his lesson, and observing (gathering evidence that will be used to explain the results). Mr. Moloku's perception of learner roles includes being prepared to learn, prepared to work collaboratively and learn from one another (Learner-learner interaction). He considered a learner a participant during the lesson despite the teaching method employed by the teacher. The learner is an active participant during his lessons.

The teacher's role in the science classroom: Mr. Moloku's main role is to design lessons that challenge his learners to think and apply knowledge to novel situations. He perceives himself as a facilitator, guide and helper to the learner. He noted that learners must be actively engaged in learning. He explained:

> I don't believe there is a lesson you can lecture throughout. If there is a way in which you can involve the learners, even if they cannot do a practical activity but involving, giving them questions, getting some of the things from them. It helps to capture their attention and to assess whether what you are saying is getting into their heads.

This takes us to another role of the teacher Mr. Moloku perceived as important. He believes getting feedback from the learners during the lesson is important in shaping his lesson and future lessons. This is important as it shows the teacher's decisions are centred on the learners.

4.3.3.3 Mr. Moloku vignette

Lesson 1: Collinear Vectors (grade 11)

The teacher had prepared a lesson on the calculation of the resultant vector for both collinear and non-collinear vectors. This was the first lesson to be observed by the evaluator and was used as a baseline lesson observation. This was before the evaluator had a meeting with the teacher on the goals of inquiry-based teaching.

The class arrived and stood at the door, waiting for the teacher to come and mark the register. The teacher met them at the door and asked the names of the learners absent that day. After marking the register the teacher asked the learners to come into the laboratory. A class of energetic grade 11 learners entered and stood by their tables waiting for their teacher to greet and ask them to take their seats. The teacher started the lesson by drawing a number of vectors on the Cartesian plane and asked the learners to identify vectors in the same direction. The learners identified two pairs of vectors, F_2 and F_4 and F_1 and F_3. The teacher emphasized the fact that F_1 and F_2 are in the same direction and parallel, but F_1 and F_3 are parallel and in opposite direction. He explained that for vectors to be either in the same direction or opposite direction they must be parallel. Such vectors that are either in the same direction or in opposite direction are referred to as collinear vectors. The teacher writes the topic on the chalkboard and looks back and says "it's today's work", and his learners open their books and start writing. He then writes the definition of collinear vectors on the whiteboard. The teacher shows the class how to get the resultant vector if the vectors are not collinear. He uses vectors F_2 and F_4. He moved F_2 from where it was and brought it before vector F_4. He then explained how to calculate the magnitude of the resultant vector. The teacher interacted with the class on how to calculate the magnitude of the resultant vector. The excerpt below is his exchange with one of the learners:

T: What is a resultant vector?

L1*:* A vector that replaces all the vector acting on an object.

[The teacher writes the learners response on the white board and makes a comment: "You are not going to write this."]

T: What is their magnitude?

L2:12

T: How did you get the 12?

L2: We have added

T: How fully can you describe that vector?

[*The teacher explains how it becomes 12N. "Where F2 starts I draw a vector up to where F4 ends".*]

The teacher repeats the same calculation and explanation using vectors F1 and F3. After writing the answer, one learner asked a question. Here we see another exchange when a learner needs clarification on the negative sign:

L: I thought you can't have a resultant force as negative.

T: I don't know what you mean. As force is a vector it will have a magnitude and direction. If it is in that direction I call negative then it's negative.

L: Like we were told that we can't give the final answer as negative.

T: Now I get what you are saying, if it's a calculation and your final answer is negative you have to give the meaning of that negative, we know what our negative means - its 2N downwards.

There was a moment where the teacher could probe the learners so as to extract the answers from them. The excerpt below is an example of such interaction:

T: Can you give me an example where it is applied in real life?

[Mr. *Moloku asked this as he moved closer to the learners*.]

L: When you are pushing a car uphill.

L: You are applying a force to the car and the car, due to gravity, is applying a force on you.

T: you will learn about it later. What about any closer examples?

L: When you drop something.

T: I see you often, two boys or two girls fighting for a chair; one is grabbing it this way and another grabbing it that way.

L: Tug of war.

T: That's a good example. In tug of war we have two groups pulling in different directions. I gave an example of two boys fighting for a chair. They are exerting forces in opposite directions. If they are exactly in the opposite direction it's either the chair remains in the same position or one is pulled. Depending on their forces. If it so happens that they are not pulling in opposite direction, what do you think will happen. Here is the chair one is pulling up and the other one sideways.

L: It will go to the one who is applying the bigger force.

The teacher proceeded to the resultant of vectors, which are perpendicular. He did examples of the calculations on the whiteboard and the learners were responding to questions when asked. There was the application of the mathematical concepts and the learners were participating all the way. The teacher then concluded with giving homework. The learners were never given an opportunity to explore and the questions were merely to confirm content knowledge.

The first lesson was teacher-centred, in which learners were limited only to short answers and were not given an opportunity to explain and discuss concepts. In this lesson the teacher was mainly working in front of the class and predominantly at the centre of the lesson. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. The tool has four basic categories: instructional factors, discourse factors, assessment factors and curriculum factors. The summative overview on the tool provides the mean score on the level of inquiry demonstrated by the different constructs under each category, sliding on a Likert scale from 1 to 4. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 4.4 Scale statistics for lesson 1 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.4	.49
Classroom discourse	1.8	.47
Assessment	2.4	.49
Curriculum	2.5	.40

The table above shows the average inquiry instruction score of 2.28 out of four on all the four categories. The overall score is *developing inquiry* stage, which is level two on the EQUIP four levels of inquiry. This lesson was teacher-centred but did show some signs of inquiry in classroom discourse. The teacher occasionally acted as a facilitator but it was for very brief moments.

4.3.3.4 Interpreting pedagogical orientation from POSTT-PS results and interview

Mr. Moloku has none of his responses in the didactic direct orientation. 20% of his responses fall in the active direct orientation. In total 20% of the responses were for the direct (non-inquiry) approaches. 70% of his responses were in guided inquiry orientation and the other 10% was found in the open inquiry orientation. In total 80% of his responses were in the inquiry orientation. Mr. Moloku views active direct as more or less the same as didactic direct since to him they both stifle (discourage) learner thinking. His main worry is the giving of the method and he says: “I am still worried about the giving of an outline of the method; it is best if they can have a design of some sort”. He believes when learners verify things in an experiment there is not much thinking. One of the motivations he gave for choosing a response in the active direct orientation was: “The learners lack background knowledge of the concept to be taught, and to save time”. This may suggest some contextual factors affecting his choice of a pedagogical approach.

The results from the POSTT-PS suggest that guided inquiry is his most preferred orientation, with 70% of his responses falling in this orientation. As a motivation to why he preferred guided inquiry, he said: “Learners should be involved in the designing and carrying out of the experiment". When asked if he really practices his guided inquiry in his classes, here is his response:

> I believe in the method, but I don't always use it. That's the truth. There are constraints like 1) time, 2) resources, 3) to some extent the type of learners that we have. I don't know whether it's the way they have been taught from lower levels. Sometimes it becomes very difficult to progress if they work in groups, to make them do the right thing and move at the pace you want them to. It becomes very difficult.

The teacher admits he does not use the method often, although it is his preferred method of teaching. In response to why he did not opt for many open inquiry responses, Mr. Moloku is of the view that learners may not arrive at what is anticipated when left to their own devices. He explained: "To some extent there must be some guidance as to what exactly we are trying to do". When asked if the learners are not capable of doing something constructive on their own, he said: "They may come up with something constructive, depending on the ability of the learners." Here we see the teacher sceptical about the ability of his learners to do any work without teacher guidance. Although he is sceptical about the method, he does not deny its possibility, provided the learners have undergone some level of training. The issue of learner preparation is an important factor that may influence inquiry-based teaching. Mr. Moloku thinks the learners and the classroom environment need to be prepared for doing inquiry investigations. His decisions seem to be influenced by a combination of epistemic and practical reasons. He is in the same environment as the other teachers in a township school, but prefers constructivist methods of teaching. The only time we see him deviating was a result of time constraints and learners unfamiliar with the taught concept.

Summary of Mr. Moloku's orientation to science teaching: Mr. Moloku's orientation was informed by his experiences as a college learner and as a teacher. First, he still has memories of his college lecturer and still uses some of his illustrations in his lessons. This experience as a college learner encouraged an interest in teaching science. He explained: "In our science education lecture at college he used to give us some good illustrations that I still use even today in my science classes. Also, my philosophy lecture, his line of thinking, I liked it - he made us think".

Mr. Moloku's college lecturer is an important influence on his beliefs about teaching, learners and learning as well as his practice as a Physical Sciences teacher. Secondly, his teaching experiences at the high school may have influenced his views on teaching, learning, and learners. This could have informed his goals and purposes of teaching science as well as his perception of learner and teacher roles.
Based on the following observations, I describe Mr. Moloku as having a guided inquiry orientation to science teaching. First, Mr. Moloku would prefer engaging learners in the exploration of the phenomenon prior to introducing phenomena to learners. Second, Mr. Moloku challenged learners to think critically and draw upon their experiences to develop explanations.

4.4 Emerging trends from pre-evaluation semi-structured interview

The pre-evaluation interviews consist of three semi-structured interviews for each teacher that was conducted in Phase One of the study. The first interview was on the teacher's educational background and teaching experience. This was followed by an interview on the teacher's pedagogical practice and finally the teacher's pedagogical practice in inquiry. The interviews were audio recorded and transcribed using the Saldana coding method where codes are condensed into categories, which subsequently culminates in the generation of themes. The analysis of these nine interviews (three for each teacher) resulted in the following themes that relate to the current practices of teachers in inquiry-based teaching and challenges in inquiry-based teaching. The challenges are separated into intrinsic and extrinsic factors.

4.4.1 Current practices in inquiry-based teaching

Theme 1: The teachers prepare learners for the investigations through pre-lab on the experiment.

There is a certain level of competence that is required from a learner to successfully go through an inquiry-based investigation. Learners normally are found to have deficiencies in this regard and it is the responsibility of the teacher to support the learners towards the goal of achieving the minimum level of competence required to navigate through an investigation. Teachers are privileged to know what their learners can and cannot do, thus are well equipped to predict the kind of support suitable for each investigation. Mr. Kapok indicated the importance of a pre-lab in the extract below from an interview:

> If it's a measurement, I demonstrate how the instrument is used first, before they can use it. We try to measure one, two, three or four measurements and ask questions making sure that they can now read the measurement on the instrument.

The teachers sometimes ask the learners to study the background information on the phenomenon under investigation. The teacher will refer the learners to similar investigation in the textbook. Mr. Moloku explained:

> Most of the investigation you find in textbooks that I am using. What I usually do, I refer them to that experiment in the textbooks. If I know I am going to carry out an experiment this week, I talk about it in class.

The excerpts above are the evidence of the support given by teachers as they prepare learners for investigations. Mr. Charles indicated in his interview on educational background that he was exposed to pre-lab classes at university and thought it was a good method to support learners in preparation for an investigation.

Theme 2: The teachers are using teacher-centred investigations in inquiry-based teaching.

The teachers are convinced their learners need clear instructions on how to conduct investigations. The teachers mentioned that the learners do not have the required skills to design experiments on their own, not even the good learners. Mr. Kapok explained the frustration:

> It will be a problem if you don't give them method, hence I said to you then give them a method whereby they will follow the method and get accurate results. With the learners I teach, especially the ones I taught last year, they will just look at the apparatus, they won't do anything. Instead, they just break the apparatus and you will account for that apparatus.

When asked about the current group of learners, which he considered to be very good, Mr. Kapok still had reservations when it came to learners coming up with their own method.

> I will not be free, because sometimes you may think learners may perform the experiment but they end up doing something you do not want. At the end you will not get the correct results, accurate results.

All the three teachers in the study highlighted the difficulties faced by learners in coming up with independent, dependent and control variables.

> In provision of the hand-outs, you explain aspects of the practical that are important, for example safety and then observations, how to record their results. You tell them the key points to watch for in the practical. (Mr. Charles)

The teachers also thought clear instructions and monitoring were for the safety of the learners. All the three teachers mentioned the need for upholding the safety of learners above everything.

Theme 3: The teachers use inquiry-type examination questions in supporting learners develop data analysis and interpretation skills.

The inquiry is a complex and multifaceted activity involving both cognitive and physical activity (Ramnarain, 2014). During an inquiry-based lesson according to the NRC (1996) inquiry includes a range of activities with a focus on describing objects and events, asking questions, constructing explanations, testing those explanations against current knowledge and communicating their ideas to others. The teachers make use of inquiry-related questions to develop the cognitive skills or engage the learners in some of the practices as with the practical work. The following excerpts are evidence of the use of inquiry related questions:

> When you teach, you take such questions where an investigation is put in theory and then questions or conclusion must be drawn from that. Then from there you make

your conclusion based on the variables that are there and the repetitions that are in those results. (Mr. Charles)

It does help, because (i) it forms part of the examination and (ii) you cannot carry out a practical for every aspect. (Mr. Charles)

The teachers use inquiry related questions (experiment-based questions) in their lessons to teach mainly cognitive skills in the inquiry. Although a study by Ramnarain (2014) suggested that greater attention needs to be paid to the formulation of inquiry-related questions in written tests and examinations, the teachers have found these useful in the teaching of inquiry process skills. The inquiry related questions can be a great opportunity for inquiry-based teaching considering the fact that schools are experiencing shortages in materials that support inquiry teaching and pen-and-paper assessment are the most feasible way to do standardized tests in Science. As recommended by Ramnarain (2014) there is a need to improve the quality of such questions so that the teaching will be multifaceted and encompassing.

The latest publication of the National Research Council, titled “A framework for K-12 Science Education” emphasizes learners experiencing inquiry-based practices and not merely learning about them (National Research Council, 2012). The term ‘practices’ is used instead of skills, to stress that engaging in inquiry requires both the physical and cognitive activity. The use of inquiry related questions is not incorporating the experimentation which is necessary for the coordination of knowledge and skill recommended by the NRC.

In addition to this, the teacher gives the learners a topic to research and the learners gather information from books, magazines, the internet and interviews:

We have what we call a research, where they go and find out information about certain aspects of science and then write a report on that. Same as you are doing. I don’t think you will go into the lab, but you can carry out interviews. (Mr. Charles)

Theme 4: Teachers prioritize the data collection phase in inquiry over other stages.

The three teachers were asked about the kind of support that they gives their learners during investigations, they emphasized the collection of data. They make sure the results are collected properly:

> I help with data collection. The results we do together, observations and everything else they do on their own. I give guidance because at times they don't know exactly what they are looking for. (Mr. Kapok)

When asked to explain how he helped with data collection, Mr. Kapok gave an example of demonstrating how an instrument is used first before the learners use it. The excerpt below is evidence of the much emphasis given to data collection, which may be interpreted as teacher control:

> If results are not collected properly, at times the whole purpose of the investigation might fail. They do it on their own, but I give maximum guidance to make sure they get the right thing. (Mr. Kapok)

The teacher here is looking for meaningful results. The collection of data is central in the investigations at township schools. The learners are given the procedure and conduct the experiment, following either the teacher directions or written procedures. The worksheet normally has questions that the learner needs to answer at the end of the experiment as they prepare to write the report. Among the questions, they are then asked the hypothesis or the investigative question. In their report, they are supposed to identify the variables, in other words, the teachers allow the learners to do the experiment without planning. The learners are then required to think about what has happened through the experiment and deduce the dependent, independent and control variable. This could be a mirror of the pen-and-paper assessments where learners are given the results of an experiment and are expected to deduce the investigative question, variables or conclusion.

Theme 5: Teachers support the learners through asking questions and making suggestions during inquiry-based teaching.

The use of questions and suggestions was found to be very useful in the success of learners during teaching. In this study, Mr. Kapok indicated in an interview that he ask questions at the beginning of his lesson and during data collection as a way of supporting his learners through the critical stages of the learning process. The beginning of the lesson is critical to him as he wants to know how much learners know about the concept he intends to teach. In probing for prior knowledge, he explained that he uses the information gathered at this stage of the lesson to make pedagogical decisions that influence his teaching.

He explained that in cases where he discovers gaps in the learners' prior knowledge, he then closes those gaps before proceeding to his 'assignment' for the day:

> Asking questions will help a teacher to know what learners already know so that I can fill in the gaps in prior knowledge. (Mr. Kapok)

Probing for prior knowledge is an important step in inquiry-based teaching. To ensure success of the lesson, teachers ask questions to support the learners in a manner close to scaffolding. The following excerpt from the interview on investigations revealed this:

> After the practical they write a draft which you must quickly check and confirm that it's okay, here watch out, why have you done this? It's like semi-marking that work before they submit the final work. It does help in that if the learner has gone wrong somewhere they can correct and understand better and get better marks for their investigation. (Mr. Charles)

The teacher asked questions to probe learners to think through a step and to remind them of some concepts that may be useful in going over the investigation. The teachers highlighted that there are moments where learners cannot proceed on their own:

> You will find that some of the learners, you might discover that they are not even moving. So not only the factor of motivation, but to say to really come up with some meaningful experiment, they are not even getting the direction so that's where you

> would maybe come in now and give a certain direction where you want them to go. (Mr. Moloku)

The excerpt above reveals that the learners may be motivated to engage in activities, but may lack the minimum competences required to navigate the investigation. The teacher will then ask them questions that will guide them through.

4.4.2 Challenges experienced in inquiry-based teaching

The challenges that are faced by teachers when enacting inquiry-based lessons can be classified into two categories: The challenges that are a result of the teacher's environment and those that are from within the teacher's pedagogical orientation and background.

4.4.2.1 Extrinsic factors

Theme 1: Inquiry-based teaching in township schools is hampered by lack of resources.

All the teachers in their study believe that their schools are inadequately resourced for inquiry-based teaching. The schools lack some physical resources for supporting inquiry-based teaching.

> In Physical Sciences, investigations are usually hampered like in our former black schools by the availability of material, and the exposure of learners to the method of scientific inquiry and scientific investigation. Usually it is like it's strange to them that you are going to experiment on this and that. (Mr. Charles).

> The classes are big and we have a shortage of equipment. Even if you might want to set up for each individual, you can't do it because of space and lack of equipment. (Mr. Kapok).

> In Physical Sciences there is some equipment we don't have in our labs and you are required to use in a practical, and most of the time you will end up just not doing the practical. (Mr. Kapok).

> In our schools, also because of the lack of equipment, not enough resources, there are not enough materials and the learner does not have the opportunity to do it, to kill it on their own. Like I have mentioned on resources, we don't have enough in our public schools. (Mr. Moloku)

In addition, the teachers also mentioned the need for a laboratory assistant to assist with the preparation and searching around for materials. Mr. Kapok highlighted that he has no time to gather all the materials that are needed for the experiment and later on to test the equipment or chemicals if they are working well. In an interview, Mr. Kapok explained:

> We don't have, probably we have one or two functional labs. We don't have a lab assistant, the materials are not enough.

The township schools face a general shortage of resources as they are formally disadvantaged due to the imbalances of the past and the teaching of science through inquiry is a new demand on the already strained resource base. In their study (Ramnarain & Schuster, 2014), they acknowledged that despite efforts by the new government to redress the historical imbalances, township schools remain poorly resourced and have scant facilities for practical work in science. In addition, Ramnarain (2015) has highlighted the fact that even though the discriminatory funding policies were reflected in all areas of school funding, the legacy of these policies is most visible in school infrastructure. The shortages are amplified by the teacher-learner ratio in township schools that is still high. One of the classes observed had 55 learners and in a class of that magnitude it is difficult to have all the materials for all the learners.

The teachers indicated the need for more supplementary materials that give the different alternatives in terms of procedure, equipment and consumables. Mr. Charles elaborated on the need to have a booklet that gives alternatives, in terms of materials and procedures to cater for the differences in the teaching contexts:

> From the schedule, we are stigmatized to say do this. We want alternatives like, if you don't have this you can use another one, because contextual factors are

> different, we are not all the same and we don't come from the same place...such things, where you have options of experiment. (Mr. Charles).

In the above excerpt Mr. Charles has mentioned the need for teaching and learning materials for inquiry-based teaching. The research into textbooks and inquiry has revealed lack of authentic inquiry-based activities in the common school textbooks (Chinn & Malhotra, 2002).

Theme 2: Inquiry-based teaching in township schools faces the challenge of unprepared learners, in term skills.

The learners need investigative skills to competently engage in inquiry. The investigative skills are classifying, communicating, measuring, designing an investigation, drawing and evaluating conclusions, formulating models, hypothesizing, identifying and controlling variables, and inferring, observing and comparing, interpreting, predicting, problem-solving and reflective skills. These are among the many skills expected from a learner in inquiry-based learning. The learner will have some of the skills as they come to the inquiry-based lesson and when in lack of some of the skills then the teacher will support them in acquiring the skill before or during the investigation:

> Generally, most learners lack the interest in them because at times they find some difficulties. Maybe there is something that's not familiar to them. I think they lack some practical aspects of science at lower grades, maybe grade 8, and grade 9. Most of the things are new to them. (Mr. Moloku)

> Those learners, they cannot even balance the equation. They cannot even take information from the periodic table. You ask a learner about force, the learner does not know anything, but the learner passed natural sciences grade 9. Those people who are teaching natural science did not major in science. (Mr. Kapok).

The teachers have highlighted the continuity in the skills acquisition process, such that if not acquired at lower grades, learners still lack the same skill at higher grade. Therefore learners bring inherent difficulties from lower grades that the teacher may need to deal with first.

Theme 3: Inquiry-based teaching demands a lot of enactment time.

The teachers indicated that the time allocated for Physical Sciences on the timetable is not enough to carry out practical work. In an interview on investigations Mr. Charles expressed his dissatisfaction with the time allocated for Physical Sciences at his school. He indicated that a thirty minutes lesson is too short to carry out a meaningful experiment and this could be having a negative effect on inquiry-based teaching.

> I don't see myself carrying out science lessons in thirty minutes, not in thirty minutes but less than thirty minutes. It's a big challenge, besides that you would wish to have an hour at least, in order to be able to carry out some of these things. (Mr. Charles)

> Not often, because that one I think needs time. When you have to do that, they might not even finish within that whole period. So the major reason why we come in and help is the time factor, we have a syllabus. We have SBA to complete, so the time will limit us. (Mr. Moloku)

Mr. Kapok shared the same sentiments when he was interviewed, he was not happy about the time allocation in the pacesetters. He finds the amount of work that needs to be covered to be more than the time allocated on the pacesetter. The same pacesetter is used by the management to evaluate him. He expressed concern about such an unfortunate situation - where teaching is no longer for understanding. The teacher according to Mr. Kapok is evaluated in terms of percentage coverage and teacher will resort to methods that are believed to cover much content. The pacesetters stipulate the dates and the amount of time spend on that particular topic.

> When you look at the topic to be taught in two hours, the experiment only on that section of the topic needs two hours and we now have 4 hours but allocated 2 hours only. You cannot go beyond these two hours. If you go beyond the two hours you won't be able to finish the syllabus. This teaching is not about understanding, it's not about the future of the learners, and it's about ATP. (Mr. Kapok)

Here we find the time as a factor in terms of length of period and the total amount of time allocated for the topic. Teachers found both to be insufficient if they decide to include investigations in their teaching.

Theme 4: Inquiry-based teaching is hampered by the demands of summative assessment.

The teachers have highlighted the pressure of summative assessment as one of the factors working against the implementation of inquiry-based learning in South African schools. As in many other nations, South African schools are measured on their performance in standardized tests and the teaching and learning are aimed at learners having good results in the standardized tests. The teachers find the pressure too high, especially when teaching the exam class, grade 12. All the stakeholders are waiting for the results of the grade 12 external examinations to measure the teacher and the school performance, such that the school management and the facilitators are after the quantity, not the quality of your results. Mr. Kapok had to explain how the facilitator tasked him to drill learners on the terms and make sure learners are good at definitions.

> Physical science is a combination of Physics and Chemistry. It is not accorded the amount of time that goes with the content that has been placed there. If you finish the syllabus in time, it's rather you were going over the content and not teaching it in depth. It's quite demanding, the amount of content. (Mr. Charles)

> The syllabus is too long, so if you want to spend time in the practical investigation you will have a challenge of trying to finish your syllabus or work schedule. (Mr. Moloku)

4.4.2.2 Intrinsic factors

Theme 1: Inquiry-based teaching is highly dependent on teacher competence.

Teacher competence is a key factor in the implementation of inquiry-based teaching in South Africa. The teachers expressed their desire to improve their current pedagogical practice. In an interview Mr. Charles mentioned the issue of teacher competence as a challenge. He spoke in his capacity as a head of a department of science and also as an individual:

> We also have a slight challenge in the competence of teachers; where a teacher is not interested in science or has limited knowledge of science, especially practical. (Mr. Charles)

> I have no problem with the practical. The part that is a little bit grey to me is the formulation of the investigative question. (Mr. Charles)

> At times there is some equipment that I can’t even use, I have to be honest. It’s there, but I can’t figure out really how to use that equipment. It becomes difficult for me to manoeuvre, but there are those refresher courses. (Mr. Kapok)

Above, Mr. Charles explained that he has challenges with formulating an investigative question. This is a key step in planning and designing an investigation. The formulation of an investigative question starts with identifying variables. As part of their reporting, the learners were expected to give the aim of the experiment and the three variables (dependent, independent and control). Mr. Moloku and Mr. Kapok indicated that their learners struggle with identifying variables, although they did not mention this as one of their challenges. The following comments by the two teachers from interview attest to this:

> In the investigation, they used to find problems in creating an investigative question and also the problem of identifying variables. (Mr. Moloku)

> Even me, as a teacher, I have my misconceptions, but once I assess them I see that on the memo that this one it's me who taught this lesson. I have a misconception, go back and do corrections and correct those misconceptions. (Mr. Kapok)

> You would find that one might not have specialized, like if am doing chemistry investigation. I specialized in physics. There are some things where I need some clarity as far as chemistry is concerned, so if we can maybe get assistance from outside in those areas it can help. (Mr. Moloku)

The different challenges cited by the teachers above are an indication that teachers have individual challenges that may require context-specific support. Mr. Moloku has a major in Physics, and felt he may need support with some of the Chemistry practical. Mr. Charles explained in an interview that he is still having challenges with formulating an investigative question. They also highlighted the inability of the 'one size fit all' professional development by the Department of Education to address their challenges, despite the fact that they are anticipating development. Mr. Charles explained that he attends most of the workshops offered by the Department of Education and unfortunately he does not gain much. They also regarded the training as haphazard and failing to reach the intended targets, and removed from the realities of the classrooms.

Theme 2: Inquiry-based teaching demands a lot of teacher preparation and planning.

The teachers indicated that inquiry required much lesson preparation and enactment time. The teachers felt that they did not have enough time to prepare and look for the materials to use:

> I teach three different subjects and physical science is a practical subject, so really having enough time to devote to setting up experiments and testing some of those things before you take them to class is a challenge. (Mr. Kapok)

The teachers even suggested the need for the Department of Education to get them laboratory assistants to help them with the gathering of the equipment and testing of the chemicals before the experiment. In addition, in interview Mr. Kapok explained that he was not interested in doing chemistry experiments since he does not want to be ashamed in front of the learners when he finds out that some of the chemicals are not giving him the expected results.

4.5 Chapter summary

This chapter presented data on the teacher profiles. These start with pedagogical orientation of the teachers as derived from the POSTT-PS instrument. The instrument assign the teacher pedagogical orientation from the responses to multiple choice questions with responses that span the spectrum of four orientations namely didactic direct, active direct, guided inquiry and open inquiry. This data comes from the first phase of the research study and attempts to meet two research objectives;

(a) to establish the current pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching, (b) to determine the challenges experienced by Physical Sciences teachers in enacting an inquiry-based teaching approach. The findings for the first objective showed that teachers in township schools were using teacher-centred investigations in inquiry-based teaching and teachers emphasize conducting an experiment, over the other stages during their inquiry-based teaching. The findings for the second research objective reveal that inquiry-based teaching in township schools is hampered by lack of resources, unprepared learners, insufficient time and pressure of summative assessments.

CHAPTER 5: SHIFTS IN PEDAGOGICAL PRACTICE

5.1 Introduction

This chapter will focus on the results from the analysis of data collected in phases II and III of a three-stage research design process. Phase Two was planning and Phase Three was implementation of the plan. The planning stage was divided into three meetings on setting goals, determining strategies and deciding on evidence for achieved goals. Planning involved the collection of qualitative data through meetings between the researcher and the teacher. Implementation (gathering evidence) is an ongoing intervention in which quantitative and qualitative data are collected from lesson observations and post-lesson reflection interview respectively.

The previous chapter presented Phase One (stock taking) - the pre-intervention interviews, instrument (POSTT-PS) and preliminary classroom observation served as a basis to understand the teacher's initial conceptual understanding of inquiry-based teaching. I was able to identify the gaps during the pre-intervention interviews, pre-intervention instrument (POSTT-PS) and the preliminary lesson observation for each teacher (the first lesson for each teacher, and agreed with the teacher during the goal setting meeting (Phase Two) on the goals that would foster improvement. In the third and final phase, I observed the lessons of each teacher by employing an inquiry-based quantitative tool called Electronic Quality of inquiry Protocol (EQUIP) which produced quantitative data that measured the teachers' level of improvement towards inquiry-based pedagogy from lesson two to lesson eight. The tool also served as a basis for documenting progress over time. The post-lesson (stimulated-recall) reflection interview in phase three served as a basis to foster attainment of goals set in phase two and produced qualitative data.

The case study approach allowed me to gain rich insight into the three Physical Sciences teachers' understandings, pedagogical practice and justification of their instructional methods through the concept of empowerment evaluation. The teachers' understandings of inquiry-based teaching methodology and their classroom practices were the main focus of the data organisation and analysis. The three steps of empowerment evaluation are merely a guide to evaluators and not necessarily the only means to conduct empowerment evaluation. In this regard the researcher included post-lesson (stimulated-recall) interviews sessions to initiate teacher reflection on their practice.

5.2 Phase II-planning

Planning involved collection of qualitative data from three meetings between the researcher and each teacher to remedy gaps identified in Phase One. The meetings were after the stock-taking was concluded and the objectives of the meeting for each teacher were (a) to set teaching practice goals towards inquiry, (b) to set strategies for achieving the set goals, (c) to identify the type of evidence required to document credible progress towards their goals. Table 5.1 captures the results of the meeting. Each teacher had his own interpretation of inquiry-based teaching, although they all agreed on the need for teacher support, ample time and resources to enact inquiry-based teaching. Their teaching goals were also different as they seemed to view the practice differently. After the meeting, each teacher was expected to implement their pedagogical strategies in class while the researcher observed each one of the lessons. After every lesson, the researcher had a post-lesson interview with the teacher in question. This post-lesson reflection interview served as a basis to understand the reasons for the teaching practice and at the same time foster attainment of goals set in this meeting.

Table 5.1 Results from the planning meetings

Participant	Teacher orientation	Teaching goals	Strategies
Mr. Charles	Active direct, presenting science as a body of knowledge and a series of hand-on activities that may not necessarily minds on.	• To ask learners investigative questions and allow data collection in an attempt to answer the questions. • To give activities that required critical thinking.	• Give learners opportunities to investigate their ideas • Let learners investigate, and come up with their own conclusions. • link science with the everyday situation of learners
Mr. Kapok	Strong active direct, presenting science as a body of knowledge and a series of hand-on activities that may not necessarily minds-on.	• To involve learners in manipulation of apparatus and collection of data. • Engage learners as much as possible in a lesson	• Integrate investigations where learners are active participants in class. • Increase learner participations through asking questions
Mr. Moloku	Guided inquiry, presenting science as inquiry	• To come up with a lesson where learners construct explanations from evidence generated from the investigation.	• Help guide learners to discover scientific concepts by asking open-ended questions. • Probe learners on their explanations and make suggestions where possible.

5.3 Phase III-implementation

This phase is the final stage (ongoing intervention) according to the stages of empowerment evaluation presented in Chapter Two, and comes after baseline and planning. It is based on quantitative and qualitative data from lesson observations and post-lesson stimulated-recall reflection interviews respectively. The quantitative data was obtained by using the EQUIP classroom observation tool mentioned earlier, and qualitative data was obtained from interview transcripts. The post-lesson stimulated recall interviews were conducted between lessons to allow for reflection on practice that could assist the teacher in revisiting some of their practices. To assist in trend progression of the teacher towards an inquiry approach in the class, the results were presented individually with each teacher's progression given separately to illuminate the evaluator's input in terms of shifting the teacher towards inquiry approach.

The account of the three teachers is given below, where the eight lessons that were analysed are presented for each teacher. The presentations include the first lesson, which is a preliminary lesson observation that served as a basis to gauge the teachers' grasp of the concept of inquiry-based teaching. The lesson was included in this section to allow for continuity, the same lesson was presented in the previous chapter as baseline.

5.3.1 Mr. Charles

The section presents eight lesson observations for Mr. Charles together with their EQUIP scores. Each lesson is a vignette and a thick description of what transpired in the lesson was given leading to an evaluation of the lesson in terms of the level of inquiry according to the EQUIP levels of inquiry.

5.3.1.1 Lesson 1: Conservation of Linear Momentum (Grade 12)

The first lesson was on proving the conservation of linear momentum. The lesson was largely teacher-centred, in which the teacher preferred to tell the answers when the learners were giving wrong answers and when the learners could not answer the questions. The purpose of the lesson activities was to demonstrate to the learners that the total linear momentum of a system will remain constant. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. The tool has four basic categories: instructional factors, discourse factors, assessment factors and curriculum factors. The summative overview on the tool provides the mean score on the level of inquiry demonstrated by the different constructs under each category, sliding on a Likert scale from 1 to 4.

Each category was then scored according to the following table, on the level of inquiry it represents. The following presents a summative overview table.

Table 5.2: Scale statistics for lesson 1 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.0	.00
Classroom discourse	1.2	.40
Assessment	1.2	.40
Curriculum	2.25	.83

The table above shows the average inquiry instruction score of 1.66 out of four on all the four categories. The overall score is the *pre-inquiry* stage, which is level one on the EQUIP four levels of inquiry. This lesson did not show any signs of inquiry on all categories. In the post-lesson stimulated recall interview, I asked the teacher probing questions as a way of setting goals for the next lesson based on the gaps identified in lesson 1. I realised the teacher preferred transmission method of teaching and we agreed to try inquiry-based teaching. We agreed on the bridging lesson where the teacher was going to introduce the learners to the process skills, before the practical work. The process skills included asking investigative questions, hypothesising, identifying variables, making observations, recording results, interpreting results and making conclusions.

5.3.1.2 Lesson 2: Heating and cooling curve (Grade 10)

The lesson came after the evaluator had a brainstorming meeting with the teacher and concluded the importance of including experiments and introducing learners to the format of the report before these experiments. The teacher greets the learners and informed them of the experiment which was coming in three days' time.

He explained to the learners what was expected of them in an experiment; in terms of the laboratory safety rules. The teacher introduced the format of writing a report on an investigation. He informed the learners that they were expected to use the same format for all their reports in Physical Sciences and the write-up was going to have the important headings; aim, variables, apparatus, safety precautions, diagram, method, observation, results, analysis and conclusion. The teacher discussed each of the steps using the experiment on the heating curve as an example. There was teacher-learner interaction as learners responded to his questions which were largely closed questions. The excerpt below is the evidence of the conversation between the teacher and some of the learners in the class:

> T: What did we say the independent variable was?
>
> L: Time
>
> T: Controlled variable: What is it in that experiment that you can keep the same such that our results are not influenced by it?
>
> L: Water
>
> T: The purity of water. We cannot take water from school and we take water from any other source. That one I am not going to write for you. I want you to think. The other one, when scientists measure the boiling or melting point of water and substances they do so at sea level. Thina, are we at sea level? We are up. The sea level is at Durban, Cape Town, Port Elizabeth. Thina we are above the sea level. We are not going to Durban to do the experiment. The altitude where we conduct the experiment is going to be the same. So any of these 3.
>
> T: The Apparatus?
>
> L: Glass beaker, test tube, thermometer, water, Bunsen burner.

T: Let's put it in a more scientific way. Let's call it a heat source. And if we are going to measure our temperature at a particular time what are we going to need?

L: A stopwatch.

T: I can say a stopwatch, cell phone stopwatch or digital watch, hot water, ice for the cooling curve, we need table salt. We record until our ice turns into a vapour or until our vapour turns into ice. I should explain here there are a lot of marks.

The teacher emphasized the importance of recording results in an experiment and coming up with a written conclusion. The learners were given an option to take notes as the discussion proceeds or wait for the teacher to finish, then copy the format at the end. The teacher then explained how the learners were supposed to write their observations, draw and analyse the graphs, identify the melting and boiling points. In conclusion, the teacher explained why the boiling temperature of water differs with the place.

The lesson was teacher-centred, in which learners were limited only to short answers and were not given an opportunity to explore and discuss concepts. In this lesson, the teacher was mainly working in front of the class and predominantly at the centre of the lesson. The purpose of the lesson activities was rote memorization of facts. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents. The mean scores for the lesson on each category are displayed in table 5.3 below.

Table 5.3: Scale statistics for lesson 2 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	1.0	.00
Classroom discourse	1.6	.49
Assessment	2.0	.63
Curriculum	1.5	.86

The table above shows the average inquiry instruction score of 1.53 out of four on all the four categories, a slight improvement from the previous. The overall score still reflects the *pre-inquiry* stage, which is level one on the EQUIP four levels of inquiry.

This lesson did show some increase in the scores for the discourse and assessment factors, although much was not expected since the lesson was largely a pre-lab. The teacher rarely acted as a facilitator and most of his engagement with the learners was in the form of oral questioning that did not lead to discussion. The teacher showed an improvement in the questioning skills, he was soliciting explanations from the learners. The teacher confirmed this in the post-lesson reflection interview.

After the lesson, I met with the teacher for the post-reflection and we discussed all the categories. I commended the teacher for the improved scores in discourse and assessment factors. The teacher acknowledged an effort was made to improve his questioning skills since our last discussion. We agreed to work on improving the discourse and instructional factors, as shown in the following excerpt:

> R: I have noticed an improvement in the questioning techniques in the lesson.
>
> T: Yes, I am working on my questioning skills as per our previous discussion.
>
> R: We need to think about the other factors like classroom curriculum and instructional factors as in the EQUIP tool.
>
> T: I need to consider that in my coming lessons, probe more and allow for discussions.

The teacher has shown an improvement in the frequency of questions. Even though the questions remain largely closed questions, he has asked more questions in lesson two than lesson one.

5.3.1.3 Lesson 3: Heating and cooling curve experiment (grade 10)

In this lesson, the teacher prepared to deliver a lesson on the heating and cooling curve of water. The lesson came after the teacher had a post-lesson reflection interview with the evaluator, where the need to include practical investigations in the lesson was discussed. The learners were introduced to the process skills in the previous lesson. The related skills included; asking investigative questions, hypothesising, identifying variables, making observations, recording results, interpreting results and making conclusions. During lesson three the teacher wanted the learners to investigate the heating and cooling curve of water. The main objective of the lesson was to allow learners to observe, collect data, record, analyse, present the results of the experiment and draw conclusions. The teacher decided to have three learners help him with carrying out of the experiment in front while the rest of the class were seated, observing and recording results.

The teacher carried out the experiment while one learner was taking the readings on the thermometer, one learner was timekeeping and the other learner was writing the temperature readings on the chalkboard from which the rest of the class took their results. After the experiment, the learners were supposed to come up with a detailed practical report. The teacher emphasized the importance of writing a practical report as explained in the following excerpt.

> Now I want us to copy this, try to write from results to analysis. I want you to write your results and analysis now so that it's your draft so that I can say that you should have done this or that. Then when you come tomorrow you do your write-up in class as individuals.

Mr Charles provided learners with the following structure for this report:

- The aim of the experiment.
- The variables (independent, dependent and control variables)
- The method
- The results
- Analysis of results
- Conclusion

This lesson had some signs of inquiry, although the circumstances of the classroom militated against inquiry-based teaching. The classroom had 52 learners and one set of apparatus for this experiment. The lesson showed some signs of inquiry; the learners were required to construct arguments based on evidence and communicating results in form of report writing. Though the larger part of the lesson was dominated by closed questions at the end of the lesson the teacher was asking open-ended questions that really engaged the learners. This is evident in this excerpt that depicts an exchange between teacher and learner:

> T: When we read in books, they say the boiling point of water is 100^{o}C, why did we miss 4^{0}C?

L: We are not at sea level

T: Correct, what else?

L: The water is not pure.

T: The tap water is not pure like what we buy from the shop. Even the one you buy from the shops has to be purified by scientists. I want you to check the results from 10 A if they are the same as ours.

The skills introduced to the learners in lesson two included; hypothesizing, identifying variables, making observations, recording and interpreting results, analysing and making conclusions. The teacher had observing, recording and practical report writing as the main objectives of lesson three. The teacher wanted the learners to formulate an explanation for their results and present their results in tables and graphs. The learners were not given enough time to interact, with teacher-learner interaction dominating the class. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents. The mean scores for the lesson on each category are displayed in table 5.4 below.

Table 5.4: Scale statistics for lesson 3 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.0	.40
Classroom discourse	2.4	.49
Assessment	2.4	.80
Curriculum	2.3	.50

The table above shows an average inquiry instruction score of 2.28 out of four on all the four categories. The overall score reflected an improvement, thus a shift from the previous score, although it is still *developing-inquiry* stage on the EQUIP levels of inquiry. This lesson showed improvements in inquiry score on all four categories. The teacher included an investigation that took away his lecturing role time. Although the ways of collecting data were still prescriptive, the teacher was now probing more, thus encouraging learner reflection. When asked during the post-lesson interview why he gave learners the procedure for data collection; the teacher mentioned that it was a School-Based Assessment (SBA) experiment and he was not supposed to alter any of the instructions. A SBA is a school-based activity that contributes up to 25% of the learner's summative assessment mark. In South African schools learners and teachers have high regard for this task and the teachers want the learners to score well in their SBA.

5.3.1.4 Lesson 4: Matter and materials (grade 10)

It's a Monday morning at Ruth High school. The teacher is waiting for the grade 10 class to arrive. They come in small groups until the class of more than fifty learners is full. The teacher greeted all the learners and tells them they were going to do an experiment. The teacher reminded them of their topic and how it links with the experiment. He introduced the terms that were important for the day that is metals, metalloids and non-metals. He then explained why the learners would want to know if a material will conduct electricity. The teacher has only one set of a circuit board, four cells and two bulbs. The class has fifty learners present that day. The teacher asked learners to form five groups and take turns to do the experiment. When the learners were about to start on the experiment the teacher reminded them about the importance of the practical write-up and the format they must follow when writing a report. He explained the difference between an independent and dependent variable. The teacher gave an acronym (CIDSCM) to help learners remember the variables. He asked the learners to pair the letters by putting the letters CID directly on top of letters SCM. The learner will then match C for Control variable with S for same, I for independent variable with C for change and D for dependent variable with M for measured. The learners would read it as the control variable that stays the same. Independent variable changes and dependent variable are measured. The excerpt below is the teacher's interaction with the first group, giving them permission to choose materials to use:

> T: But then can we test every substance in the universe. Can we?
>
> L: No (in a chorus)

> T: So we can pick a few that we can use as a sample and later on generalize on that. Right?
>
> L: Yes
>
> T: I thought some of you I was going to send outside to pick up some of the material, but it's raining. But I have iron, copper, perplex, steel, paper, plastic, chromium and wood. If you have some of the materials in your bags we can use them, then you can add them when you write up. First, before I begin I can check to say does this bulb light. [*Teacher demonstrates*]. Everything I am using here is conducting electricity. Now I change now between this terminal and the cell, let me put this material and check whether the light continues. If it doesn't or it does, that's what we want to find out. Then from there, you have the method, observation, results, interpretation of results and conclusion. From here you have to write the method in your own English and we write it in past participle.

The teacher proceeds to explain the method to the rest of the learners who were not carrying out the experiment. He gave them an example of the tense they were supposed to use. The excerpt below is the evidence of the teacher giving the example to the remainder of the class:

> The experiment was set as shown in the diagram. A test run was done to see whether the bulb glows, after that material was used to check whether they did conduct electricity and the results were noted in the table. I did not say I, I did not say you, I did not say us. I talked about things that happened in the past or recent past. If it did light it means the material conducts electricity and if it did not light it means it's a non-conductor of electricity:

When the second group was about to start the teacher joined the group and the excerpt below is their conversation on setting up the circuit:

> T: What is that?
>
> L: Circuit board.
>
> T: One can do it so that we can see guys, somebody hold the cell, and does it light?

L: No

T: So you tick accordingly. Those you have done, put them aside. This iron you can put it there. You see that. Be fast, be fast.

T: Perspex

L: Hmm can we try rubber

T: Yes, try everything. Take cloth. Bring everything you can test. Anyone with some other material. What material is that?

L: Zinc

T: Don’t bend that. A five rand coin. What is that material?

L: Gold and…

T: Nickel and copper.

The teacher was shifting from being controlling to being facilitative. The learners are seen to be actively engaged in activities with evidence of exploration. Although there was a shortage of equipment, learners had a fair chance of exploration and learners could make sense of the idea of a conductor. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.5: Scale statistics for lesson 4 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.6	.49
Classroom discourse	2.4	.40
Assessment	2.2	.74
Curriculum	2.5	.71

The table above shows an average inquiry instruction score of 2.43 out of four on all the four categories. The overall score depicts a *developing-inquiry* stage. This lesson was now showing some improvement in terms of instructional factors and curriculum factors, although it registered a drop in the classroom discourse and assessment factors. The teacher was prescriptive on the ways of collecting data during the experiment. The post-lesson discussion was based on the ways in which the teacher can improve the classroom discourse. The teacher was confident he could improve his questioning skills and improve on the learner-to-learner interaction during the lesson. The excerpt below shows the discussion between them and the teacher:

> R: I really commend you for registering a three on the curriculum factors. I also see a slight improvement in instructional factors. What are some of your challenges?
>
> T: The lesson was hampered by the shortage of equipment. Imagine one set of apparatus for more than fifty learners.
>
> R: Did you manage to achieve your objectives for the lesson?
>
> T: Partially, I managed to get them to perform the practical and report on the practical, but could not give them ample time for the interpretation of the results.
>
> R: Do you think a learner will know why a metal is a conductor of electricity and wood is not a conductor from what you have accomplished today?
>
> T: As I said, I did not manage to get to that, because of time.

The excerpt above is a discussion between the teacher and the critical friend. I managed to support the teacher to the extent that he can reflect on the lesson and plan for the coming lesson. The teacher's objectives were getting the learners to do the practical, observe and collect results, then report on the practical. I thought it was necessary for the learners to have an idea of what makes a substance a conductor of electricity so that even when the learner did not use the substance in the practical they can further classify on their own. The teacher promised to include an explanation in the coming lessons.

5.3.1.5 Lesson 5: Newton's laws- acceleration vs force (Grade 11)

The teacher greeted the class and displayed a format of the practical write-up on the chalkboard. He started to discuss each bullet on the write-up format with the learners. He instructed the learners to copy it in their books. He discussed the aim, variables, apparatus, and tables of results, analysis, and conclusion. When asked why he started the lesson by giving them the format the teacher said the learners need to know the correct way of reporting their finding since it was an SBA. Much emphasis on the write-up format has been observed. The teacher then checked for prior knowledge from the learners on the topic for the day. He asked the learners to recite for him Newton's laws. As each law was given he would explain further to make sure the learners understand it fully. The excerpt below is one such conversation between Mr. Charles and one learner when he was asking for the first law.

> T: Can anyone give me the first law?
>
> L: An object will remain at rest or move with constant velocity unless acted upon by an unbalanced force.
>
> T: Mina I call that law, seated. You remain seated like this until you decide to stand up or I was walking nicely until I bumped into that thing. What happened? I stopped walking unless something happens. That law is a non-formula law, it is a descriptive law. If you are seated in a kombi nicely going to town, the driver is going at 120km/h. you know taxi drivers like dirty brakes. What happens to you?
>
> L: You go forward
>
> T: You continue to move, that is why we fly out of the windows in an accident, because the body will say 'mina ngiyahamba 120', but the car has stopped suddenly. That's why we put on seat belts. It describes everyday situations.

He proceeded to tell the learners that they were going to verify Newton's second law of motion. He told them the law and the three variables to be investigated. He proceeded to write on the chalkboard the materials needed. He explained everything that was required for the experiment. The excerpt below is the teacher's explanation prior to the experiment:

> T: The trolley that we are going to use is called a dynamic trolley, a 600g mass piece, rubber band and a tape measure. Our force is going to be the stretch in the rubber bands. If I take two rubber bands it's different from one rubber band. We are going to call the force in one rubber band one unit force. For the mass this is 600g it's already scaled. Dynamic means it can move.

The teacher then asked a few questions to assess if the learners were ready to carry out the experiment on their own. The learners responded very well, especially the group that was in front. The learners could clearly state the independent, dependent and controlled variable for the experiment. The excerpt below is the evidence of a conversation between one learner and the teacher on variables:

> T: What are we going to measure?
>
> L: Distance
>
> T: So the distance is our dependent variable. What we have chosen on our own.
>
> L: Rubber band
>
> T: What is it representing?
>
> L: The force. Yes, another one?
>
> L: Mass
>
> T: Can we choose how much it is going to move?
>
> L: No
>
> T: Why should the floor be spotlessly clean?
>
> L: So that there are no disturbances.

The teacher then gave the learners a summary of the method as he demonstrated with one set of equipment. He drew two tables on the chalkboard and asked the learners to record their results as shown in the tables. The learners were left alone to do the experiment while the teacher observed from a distance. The learners the next day were going to write a practical test on the experiment.

In this particular lesson, Mr. Charles frequently acted as facilitator. The teacher started by assessing learner prior knowledge and partially modified instruction based on this knowledge. His learners were consistently and effectively active as learners throughout the lesson. The learners are seen to be actively engaged in activities with evidence of exploration. The teacher often followed-up responses with an engaging probe that required the learner to justify reasoning. Although there is usually a shortage of equipment at this school, on that particular day there was enough for all the groups. The teacher asked for equipment from another school. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.6: Scale statistics for lesson 5 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	3.2	.40
Classroom discourse	2.6	.49
Assessment	3.0	.00
Curriculum	2.75	1.30

The table above shows an average inquiry instruction score of 2.89 out of four on all the four categories. The overall score is *developing inquiry* stage on the EQUIP levels of inquiry. This lesson showed some improvement in terms of instructional factors, classroom discourse, and assessment factors, although it registered a drop in the curriculum factors. The teacher was still prescriptive on the ways of collecting data during the experiment. In the post-lesson interview, the evaluator acknowledged the improvement so far and encouraged the teacher to give his learners another experiment. The excerpt below shows the discussion between the critical friend and the teacher on finding another investigation:

> R: I see you prefer to give the table of results and clearly state to the learners what they need to measure, today you were even demonstrating to them.
>
> T: Yes, this is an SBA, like I said we cannot alter it. It's a practical for marks and you don't want your learners to perform badly on it. Besides the results are the critical part of any investigation at this level, it must be done well otherwise the whole purpose of the practical is defeated. Today they were supposed to see the direct relationship between force and acceleration, but they were not measuring any of the two variables.
>
> R: Do you think your learners managed to link distance covered by the trolley with acceleration and the number of rubber bands used with force?
>
> T: Yes, I am confident they did. That demonstration was not my original plan, but I had to change it so that the learners can connect the dots.
>
> R: How about you give another lesson and now it won't be SBA and allow your learners to design the method and table of results on their own.
>
> T: Yes, it is possible; the Second Law also has the relationship between mass and acceleration. We can do that in the next lesson.

The teacher managed to explain Newton's second law, but could not get enough time to get feedback from the learners about the investigation. He was confident that his learners deduced the relationship between acceleration and net force.

5.3.1.6 Lesson 6: Newton's laws- acceleration versus mass (Grade 11)

The teacher prepared to teach Newton's second law using an experiment where the learners investigated the relationship between mass and acceleration. The learners had investigated the relationship between acceleration and force in their previous lesson and they were now familiar with the equipment. The learners were supposed to design an investigation to find the relationship between acceleration and mass. The teacher provided the learners with all their equipment and asked them to come up with a method and then carry out the experiment. The learners are working in groups of fives and their task is to come up with a method to prove the relationship between acceleration and mass. The learners sat in their groups and started discussions on how to find the relationship between mass and acceleration. This was a moment of planning that required an understanding of the variables at stake. The following excerpt is a conversation between learners in one group:

> L1: What are we looking at?
> L2: We want to change mass and see how fast the trolley will go.
> L3: So what mass are we changing? Is it the mass of the trolley?
> L1: Are we allowed to use different trolleys or trolleys of different mass?
> L3: We are given only one trolley, then it means we do not have that option.
> L2: We can change the mass of the trolley we have.
> L4: How? Can we remove some of the mass on it, but how?
> L5: I think we can add instead.

The teacher then asked learner 5 what he meant by adding. The learner suggested they add another trolley like they did in the previous experiment, where they added more force through adding the rubber bands. Then, in this case, they were supposed to use more trolleys to increase the mass. The teacher looked at the steps that were listed on their plan and asked some probing questions for them to reconsider some things. The excerpt below is the evidence of the teacher probing the learners for the answers to make their method more plausible:

T: Do you think the rail can take more than three trolleys?

L: Yes.

T: When they are three what will be the mass of the system?

L: The mass of the three plus the weight pulling them.

T: You do not have such an option because you are given one trolley and some masses over there. Each mass is equivalent to the mass of a trolley. So what do you think?

L: We put the mass on top of the trolley.

T: Then?

L: That will be a trolley of different mass.

T: You can proceed and do the experiment.

Mr. Charles moved to the next group that was already performing the experiment. The teacher asked the group members for their plan and checked their plan which to him was perfect. The teacher asked the learners to reduce their angle of inclination, to avoid breaking the trolley when acceleration is too high. The teacher went around all the groups and then asked all the groups to record their information in the table of their choice and use the results to draw a graph of the relationship between acceleration and mass. The learners could easily get the dependent and independent variable. The teacher could probe the learners to figure out the controlled variable. The excerpt below is the evidence of a conversation between one learner and the teacher on the variables:

T: What is the controlled variable in this experiment?

L: Mass

T: Mass of what?

L: A mass of trolley

T: What is it that I want with the rubber band?

L: A mass of trolley?

T: Then can the same mass be the controlled variable?

L: No

T: What are you keeping constant?

The learners in the group kept quiet, but they had finished the experiment and their results were showing the correct relationship between mass and acceleration. The teacher then asked the learners from each group to come and present their results and conclusion. Each group was supposed to give a description of how they carried out the experiment and the challenges faced.

Mr. Charles allowed the learner's flexibility to design and carry out their own investigations. The teacher did not assess learner prior knowledge. When asked after the lesson he said the experiment was a follow-up to lesson five and the learners were still fresh on Newton’s second law, thus there was no need to check their knowledge. The learners were actively engaged in activities with evidence of planning and exploration. We see evidence of important learner-to-learner interaction. The equipment was enough for all the groups, although there was no variety. All the learners were restricted to using the trolleys and mass pieces to design their experiment. The results of an analysis using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in the classroom is given in table 5.7 below.

Table 5.7: Scale statistics for lesson 6 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	3.0	.00
Classroom discourse	2.6	.49
Assessment	2.8	.40
Curriculum	3.25	.43

The table above shows an average inquiry instruction score of 2.91 out of four on all the four categories. The overall score is *developing inquiry* stage on the EQUIP levels of inquiry. This lesson showed some improvements in curriculum factors compared to the previous lesson. There was a drop in the instructional factors and assessment factors. The teacher could account for the drop in the instructional factors. The discussion after the lesson was mainly on improving all the indicators as shown in the excerpt below:

R: Mr. Charles you have managed to come up with an inquiry lesson where the method is not given to the learners and the learners are free to record results on their own. How was the experience today?

T: It was not easy, my learners are not used to working without an outline of the method, but I have learned that it is possible with teacher support. At one time I felt like I am now giving too much support, but I think that was the only way.

R: Are there any areas you may improve?

T: I could not start with the usual checking of the prior knowledge since previously we looked at the same law and I expected the learners to know. I only looked at their plans and made some adjustments here and there. I can also use the same plans to probe and correct misconceptions.

The critical friend and the teacher agreed on improving the class discourse through asking open-ended questions and encouraging class discussion. There must be an effort made by the teacher to establish a class discussion that can end up being driven by the ideas or questions raised by the learners.

5.3.1.7 Lesson 7: Chemical change (Grade 11)

The teacher is going to teach stoichiometry using an acid-base reaction that proceeds with the evolution of carbon dioxide gas. The learners are given two options; either to trap the gas evolved or measure the change in mass as the reaction proceeds. The reaction was between calcium carbonate and hydrochloric acid. The volume of the trapped carbon dioxide in a syringe was recorded and the mass of calcium carbonate that reacted determined. If learners decide to use the balance, change in mass is attributed to the carbon dioxide evolved. The learners are provided with the worksheet with the guidelines on how to trap the gas and how to use a balance to measure any changes in mass. The objective of the lesson was for the learners to come up with a flow chart of the important things to consider when performing stoichiometric calculations. The learners started by planning in their groups, carried out the experiment and perform the calculations. The calculations were then used to formulate a flow chart or a concept map. The excerpt below is the conversation between the teacher and one of the learners:

L: Can I have your attention sir

T: What do you want?

L: Mass of $CaCO_3$

T: You want $CaCO_3$ where does the volume come in?

L: That's the number of moles

T: It not numbers of moles its volume. You are clear now

L: We must get the number of moles

Each group was given forty minutes to do the calculations. The teacher moves to the next group. He finds that the group members are lost and he starts afresh to explain the theory behind the experiment. The learners interacted with each other for the thirty minutes and the excerpt below shows the evidence of learner to learner interactions.

L1: We are supposed to calculate percentage purity and we don't understand. From last year we were using mass over total mass x100.

L3: We must get the mass of $CaCO_3$

L2: We must get the mass of the impure

L3: Did you get the formula?

L4: Yes. $CaCO_3$.

L1: Let's calculate the molar mass first. Let's check from the periodic table. [*The learners calculate the molar mass of $CaCO_3$. It's 100, 08 g mol.*]

L2: Here is the formula for percentage purity (mass of compound ÷ mass of sample x 100%).

L3: What is a compound?

L4: The combination of Calcium, Carbon, and Oxygen

L1: What is the sample?

L2: The sample is what we started with.

L3: Compound. $CaCO_3$ so we calculate the molar mass of $CaCO_3$. We already have it.

L4: Who is having the formula sheet?

L2: The formula says the number of moles equals mass over molar mass

L1: We don't have a number of moles and this volume is not for $CaCO_3$. Let's check from this book

L2: Do you have a textbook? Let's see here is an example of percentage purity.

L1: They said they gave them 50g. Thus the sample. The mass of the residue was 4g.

L3: Here they say the mass of pure product = 50-4 = 46g

L2: How do we calculate the number of moles? I don't know what I am supposed to do

L1: How do we get the mass of the pure substance?

The teacher visited one group and gave them guidance as they seemed to be struggling with the calculations. The teacher reminded them of the molar ratio and the molar gas volume at standard temperature and pressure. The teacher was worried since the group did not even have a periodic table. The following excerpt is the conversation of the teacher with the learners of the group:

T: Where is the periodic table, you can't do chemistry without a periodic table. You must also decide if you are to use kilograms or grams for your calculations.

L1: I will use kilograms

T: Then you must convert this to kg

L4: You multiply by 1000

L2: No divide

L4: I was not lost that much

L1: We were struggling with a question, this simple.

L1: How do we calculate the next question?

L2: Let ask Sir

L1: We can't ask everything from the teacher

L3: But we know the number of moles.

Mr. Charles frequently acted as a facilitator in this particular lesson and there was a notable improvement in learner-to-learner interactions. His learners were consistently and effectively active as learners throughout the lesson. The learners are seen to be actively engaged in activities with evidence of exploration. The learners often followed up responses with an engaging probe that required the learner to justify reasoning. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.8: Scale statistics for lesson 7 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	3.0	.00
Classroom discourse	2.8	.40
Assessment	3.0	.40
Curriculum	3.25	.43

The table above shows an average inquiry instruction score of 3.01 out of four on all the four categories. The overall score is *proficient inquiry* stage on the EQUIP levels of inquiry. This lesson was now showing some improvement in terms of classroom discourse and assessment factors. The post-lesson interview between the teacher and the evaluator was on improving the classroom discourse, assessment, and curriculum factors. The challenges and immediate solutions were discussed and the teacher promised to implement the resolutions of the interview in the next lesson. The following excerpt shows the intervention by the critical friend:

> R: I see that the learners are now engaged in fruitful discussions during the lesson.
> T: It's amazing the potential that they have and sometimes we do not tap into it. I never imagined my class having all the group discussions like that. I thought it was time-consuming and would be difficult to manage. Yes, it's demanding on the part of the teacher, but once in a while it's worth the trouble especially with topics that are carried over to grade 12. My questioning skills also have changed, we are all changing. When I started I was worried about the correct answer, but now my questions are directed towards helping them to answer their own questions.

The teacher is showing signs of change in the way he perceives things as a result of the reflection-on action facilitated by the critical friend. The teacher has shifted from just dismissing the wrong answers and stating the correct answer to a prolonged engagement whereby learner justify their responses.

5.3.1.8 Lesson 8: Stoichiometry (Grade 11)

The teacher seemed to be relaxed that day compared to the previous lesson. He welcomed the class and asked if all the groups were ready to present their calculations. The teacher gave a summary of what learners did the previous day and asked the groups to take five minutes to finalise their presentations while he was busy at his table. At the end of the five minutes of preparation the teacher then asked the first group to present. The excerpt below is the interaction between the teacher and the presenter for group one after the presentation:

L1: Stoichiometry involves the ratio of atoms, molecules in a chemical reaction.

T: What do you say guys? Are we in agreement?

L: Yes

T: Yes? What about the kind of atoms that are reacting. You said it about the ratio of atoms. Let's say for argument sake I say hydrogen + oxygen give us water. Then I balance it, it becomes 2:1:2. It tells us the quality. When you say quality you say what it is. It tells us the quantity that is how many. Ratio and type of atoms involved. It's not like mathematics when you say 1 and 1 give me 2.

L: The formula says the mass of compounds over the mass of sample x100

T: What do you have on the data?

L1: Mass of the sample.

T: How do you then find the mass of the compound?

L1: We find the number of moles first.

T: How do you get the number of moles?

L: We know the ratio is 1:1:1 then the number of moles is the volume of the gas produced divide by the molar gas volume.

T: You need to calculate the number of moles first then calculate the mass.

The teacher allowed the second group to present. The learners were asking their own questions as the representative of a group presents in front. The teacher then had a conversation with the group representative at the end of the presentation. The excerpt below is the evidence of the conversation between the teacher and the presenter:

L: We must use the number of moles already known then we use the formula number of moles equals mass divided by molar mass. [*The learner calculated but got wrong units on the answer. He writes kilograms instead of grams*]

T: Check here as to work it out. Did you see something?

L2: Presentation.

T: Any questions here.

L1: If I wrongly calculated in the first question, and then use it in the next question do I get full marks.

T: The teacher will work with your wrong answer. It's knowing how to do things which is far more important than getting the answer.

The teacher then invited group three to present. The group had nothing to present. The teacher was not impressed with the group but took an initiative to assist them through the whole activity. He asked their representative to go in front and the whole class assisted them to come up with the necessary calculations and flow diagram. The excerpt below is the evidence of the teacher assisting group three with the calculations:

L: We did not do it

T: Is it a question of knowing or you having no idea.

L2: No idea. We don't even know what to do.

T: What do you want?

L2: Mass of $CaCO_3$

T: Where do 2, 3 dm^3 come from?

L: Are they not the number of moles

T: That's volume. Are you clear?

L5: I think we can use this formula to calculate the number of moles.

L6: Can we not divide the dm^3 by 1000

T: What are you saying?

L: We used our volume to find out numbers of moles for CO_2

T: Do we need a number of moles to calculate molar mass?

L: We are trying to find our mass

T: For What?

L: $CaCO_3$

T: You use your volume of CO_2 to find how many moles are there in the volume. What are you going to do with that number of moles?

L: We are going to find the mass, and we substitute in the formula for percentage of purity.

T: Is your equation balanced, let check. Its balance then the molar ratio is 1:1:1. If I know the number of moles of CO_2 then it's the same for all. If I have 0, 2 moles of CO_2 then what the number of moles of $CaCO_3$

L: 0.2 moles

T: Remember from Grade 10. The principle of conservation of mass. If I have 1000 of hydrogen and four oxygen only 8 hydrogens will react.

The rest will remain like that.

L: Since we have calculated the number of moles, then the number of moles are all the same

L5: What is the question saying? Calculate the mass of $CaCO_3$. Then why are you saying the mass of CO_2.

L6: We have already been given the mass but you are looking for it again.

L5: Guys what do we want here?

L6: Isn't here we have the mass of $CaCO_3$? The mass of CO_2 is the mass of the compound.

In this particular lesson, Mr. Charles was largely a facilitator. His learners were consistently and effectively active as learners throughout the lesson. The teacher often followed-up responses with an engaging probe that required the learner to justify reasoning. The learner was presented with opportunities to make sense of the ideas and synthesize the concepts. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.9: Scale statistics for lesson 8 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	3.4	.49
Classroom discourse	3.2	.75
Assessment	3.0	1.10
Curriculum	3.0	.00

The table above shows an average inquiry instruction score of 3.15 out of four on the mean score of all the four categories. The overall score shows that the *Proficient inquiry* was realized as explained in the EQUIP tool. This lesson showed an improvement in all the categories. The post-lesson interview had a review of the lessons from the first lesson on the projectile motion to the current lesson. The teacher generally felt the experience was worthwhile. He has built confidence and overcame the scare of enacting inquiry in his classroom and acknowledged he benefited from the experience. The following excerpt is extracted from their interview:

> R: We have managed to have eight lessons on inquiry, what are your assessment so far?
>
> T: When you first came with your research, I want to be honest, I just said it's one of the researchers asking for information. I realized later when I was teaching that I remembered what we were discussing and I included it in my teaching. I have changed the way I start my lessons. I want to make sure I engage the learners and have something for them to investigate. It can even be a practical investigative question; sometimes I give them results to analyze, just to have that component of inquiry. I thought it was a nightmare to include practical work in my teaching. But it's not that bad.
>
> R: What evidence do we have? What can I tell the teacher in the next school who want to learn about inquiry?
>
> T: I have seen my learners improving, their ability to construct a meaningful argument from their results. At first, I thought the inquiry is about letting learners search for the answers, but I have realized there is more to it. It's about how I engage them, it's about the exploration, which can be guided by the teacher, and it's about learners making use of their experimental results to come up with arguments. I think I need to split these skills to lower grades and build on them.
>
> R: Can I conclude that the experience was worthwhile?
>
> T: The discussions after the lessons were informative. There are things I have not asked myself about my teaching for a while and I have managed to look at my objectives again. Sometimes we get carried away by the need to make learners pass their matric and lose the main objective to make our leaners understand the subject. Include me in your next research program.

Mr. Charles has increased understanding of inquiry as shown from his descriptions of an inquiry lesson from the start of the study to the end. The teacher moved from describing inquiry more generally to a more nuanced description that includes exploration, data collection and arguing from evidence. The excerpt below asserts to that:

> It is a type of teaching where you don't provide ready-made answers to learners. You let them experiment, investigate, come up with their own conclusions about certain concepts in science. It's not like spoon-feeding them, they have to experiment and inquire.

The teacher differentiates between transmission and inquiry-based teaching. He also recognises the importance of conducting an investigation and drawing conclusions.

5.3.1.9 Cumulative summative percentage inquiry scores per lesson

The section presents a summary of the quantitative data generated from the EQUIP from the first lesson to the last lesson observed. Each of the categories is presented from lesson one to lesson eight. The last column shows the percentage inquiry per lesson, which gives a snap shot of the trend from lesson one to eight. The percentage inquiry per lesson was calculated from the total scores of the four indicators expressed as a percentage of the possible score. Thus, the comprehensive total scores was then divided by the possible score (16) and multiplied by 100 to get percentage inquiry per lesson.

Table 5.10: Percentage inquiry in different lessons comprehensive score per category

Lesson number	Instructional factors (4)	Classroom discourse (4)	Assessment (4)	Curriculum (4)	Comprehensive total score (16)	Percentage Inquiry per lesson (100)
1	2.0	1.2	1.2	2.25	6.65	41.56
2	1.0	1.6	2.0	1.50	6.10	38.13
3	2.0	2.4	2.4	2.30	9.10	56.88
4	2.6	2.4	2.2	2.50	9.70	60.63
5	3.2	2.6	3.0	2.75	11.55	72.19
6	3.0	2.6	2.8	3.25	11.65	72.81
7	3.0	2.8	3.0	3.25	12.05	75.31
8	3.4	3.2	3.0	3.00	12.60	78.75

5.3.1.10 Mr. Charles summary

The teacher's overall inquiry instructional practice was scored based on the four categories as depicted on each lesson EQUIP tool; instructional factors, discourse factors, assessment factors, and curriculum factors. In the first two lessons, the teacher predominantly lectured and was the centre of the focus, thus qualified as *pre-inquiry*. The learners were not engaged in any exploration or meaningful learner to learner interaction. The teacher was asking mainly closed questions and could not successfully engage learners in discussions. There was a general improvement in the inquiry score from lesson three to lesson six, the teacher is still teacher-centred but with some active engagement of learners. His lesson was still prescriptive but not in everything and qualified as *developing-inquiry*. The teacher's questions were now a mixture of closed and open questions. The teacher began to probe the learners' answers and he gradually assumed a facilitator-role in some instances during the lesson. The teacher finally managed to achieve *proficient-inquiry* in lesson seven and eight. The lessons were largely learner-centred and the focus was on the learners being active. The learners were engaged at all stages of the lesson including giving explanations. The evaluator would question Mr Charles decisions and make him reflect on his teaching.

5.3.2 Mr. Kapok

The section presents eight lesson observations for Mr. Kapok together with their EQUIP scores. Each lesson is a vignette and a thick description of what transpired in the lesson was given leading to an evaluation of the lesson in terms of the level of inquiry according to the EQUIP levels of inquiry.

5.3.2.1 Lesson 1: Resistors in series and parallel (Grade 10)

This lesson served as a basis for baseline assessment to gauge the teachers' conception of teaching using inquiry method. Mr. Kapok is teaching Series and parallel connection of resistors to a grade 10 class. The lesson took place after the interview in which the teacher showed a partial understanding of the inquiry approach. The lesson was on Electric circuits and the teacher wanted to establish the difference between resistors in series and resistors connected in parallel.

The teacher started by greeting the learners and asking them to go into their usual groups. He had already placed on the table's pages with diagrams of Electric circuits. The class is having forty learners and divided into eight groups. The learners are eager to learn and they have their notebooks. The teacher started the lesson by assessing learner prior knowledge. The following excerpt is the evidence of the interaction between the teacher and the learners:

> T: How many bulbs are there in circuit A?
>
> L: One
>
> T: What is the difference between circuit B and circuit C?
>
> L: In circuit B the bulbs are connected in series and in circuit C the bulbs are connected in parallel" responded the learner.

The teacher started with grouping the learners and giving them diagrams to ponder on, unfortunately, he did not give them time to come up with their own conclusions rather he asked them questions about the circuit diagrams. When he realized that the learners knew the parallel and series connection, he then proceeded to calculations. Mr. Kapok used prior knowledge and to make a decision on the structure of his lesson. Mr. Kapok says as he draws a diagram on the chalkboard:

> T: Let me start with series. Now we are going to calculate the total resistance of the circuits. The total resistance of the resistors connected in series is not the same as the total resistance of the resistors connected in parallel.

Mr. Kapok writes the formula of calculating the resistance of the resistors in series and asked the learners to calculate the resistance. There was talking as the learners shared ideas and attempt the question. Mr. Kapok walks around the class and comes back to the chalkboard. He did the question on the chalkboard with the class. After getting the answer Mr. Kapok asked the learners to calculate the resistance of the parallel connection using the given formula. There is some noise as the learners try to figure out the calculation. The teacher moves around and checks their calculation.

The following excerpt demonstrates how the teacher engaged the learners as he went around the groups to check the progress and possibly offer assistance:

> T: We now have the total resistance of parallel and total resistance of the series connection. What do you notice about R-parallel and R-series?

The group remained quiet. He starts to explain:

> T: Look at the resistors in series the total resistance is 5 ohms and the two resistors are 2 and 3 ohms. Look at the total resistance of the resistors in parallel, its 1, 2 ohms which are smaller than both resistors. It means if resistors are in series connection the total resistance is more than their individual resistances and in parallel, the total resistance is smaller than any of the resistors. If you want to increase the resistance of the resistors do you connect them in parallel or in series?"
>
> L1: We connect them in series."
>
> T: When you want to increase the resistance of the resistors you connect them in series and when you want to decrease the resistance of the resistors you connect them parallel.

The teacher also used metaphor to explain concepts. The excerpt below is the evidence of the use of metaphor to explain science concepts:

> T: Guys, the greater the resistance the lower the current. The smaller the resistance the greater the current. Are we all together? When you think about the speed humps in the road, if we look at the car as the current the humps affect the speed of the car. If the speed hump is too big, it means the car won't pass. The same with current if the resistor is too big the current won't pass. That's why we connect the voltmeter in parallel because it has high resistance and current won't pass through if it's in series.

There were also moments when learners interacted with each other, especially when the teacher asked the open-ended questions:

> T: The greater the resistance, the lower the current. The smaller the resistance the higher the current. From the two circuits we looked at today. Which one has a higher current?
>
> L1: The circuit with resistors in series.
>
> L2: The circuit with resistors in parallel.
>
> T: Why do you say it's the circuit with resistors in parallel?
>
> L2: The circuit with resistors in parallel has smaller resistance, thus more current"
>
> T: That's correct, also resistors that are connected in series have the same current. If you know the current of one of the resistors then you know the current of all, but with the resistors connected in parallel the current divides. Unless the resistors are the same their current is going to be different. In this case, they are different.

The lesson is largely teacher-dominated, although there were moments of teacher-to-learner interaction and learner-to-learner interaction. The teacher was not patient enough to probe learners deeply to extract answers from them, but chose to give them the required content as he went. The teacher had an activity in mind that would engage the learners. He started his lesson well with questions that could test the learner's prior knowledge on electricity, especially electric circuits. The learners could respond to questions well, although the questions in the majority were closed questions. The teacher asked open-ended questions, especially at the end of the lesson where learners needed to explain and justify their answers. The learners were not given an opportunity to explore, by performing relevant practical investigations. An opportunity was missed where learners were supposed to set up a circuit and record the voltage and current on their own. The EQUIP inquiry classroom observation tool was employed to measure extent of inquiry teaching that took place in this lesson. The tool has four basic categories: instructional factors, discourse factors, assessment factors, and curriculum factors. The tool provides the mean score on the level of inquiry demonstrated by the different constructs under each category, sliding on a Likert scale from 1 to 4. Each category was then scored according to the following table 5.11, on the level of inquiry it represents.

Table 5.11: Scale statistics for lesson 1 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.0	.63
Classroom discourse	2.6	.49
Assessment	2.4	.49
Curriculum	2.3	.47

The table above shows the average inquiry instruction score of 2.33 out of four on all the four categories. The overall score is *developing inquiry* stage, which is level two on the EQUIP four levels of inquiry. This lesson was teacher-centred but did show some signs of inquiry on classroom discourse. The teacher occasionally acted as a facilitator but it was for very brief moments. This correlates well with the results of the POSTT-PS which predicted a non-inquiry orientation for Mr. Kapok with an overall mean orientation of 2.7 on the pedagogical orientation scale. An orientation of 2.7 is shifted toward inquiry, although still teacher-centred.

5.3.2.2 Lesson 2: Forces (Grade 12)

The teacher has prepared a lesson on Newton's laws and is using a simulation of an experiment where learners are supposed to collect information from the computer and answer the questions that follow. The learners are supposed to record the mass of the objects. The teacher uses the questions to discuss concepts of interest. The learners are familiar with Newton's laws and they have covered the work in the previous grade. The class is generally noisy on a Monday morning and the learners have a lot of talking to do. The teacher greets the class and proceeds to one learner to state Newton's second law in words. The teacher told the learners he is not going to define the laws as they have done this in grade eleven. The teacher explains to the learners how they are supposed to extract information when given a question. He gave an example of two objects connected by a light inextensible string and writes the question on the chalkboard. The teacher leads the discussion as the class collects the necessary information from the question he gave. The following excerpt is the evidence of the interaction between the teacher and the learners:

L1: Mass of 12kg

T: Mass of object one is equals to 12kg and what else is given

L2: Be v initial

T. Why v initial? Can you raise your voice?

L: The object is at rest, means velocity is equal to zero.

L2: Frictional force

T: For which object

L: For 12 kg

T: What type of frictional force is that?

L: Static Friction.

The teacher asks the learners probing questions to check their understanding of concepts. In the excerpt below the teacher pretends as if he is not clear about the concept of tension so as to probe more. The learners responded and the teacher could easily see the misconception and correct the misconception.

L: Tension

T: Is it for object A or object B

L: Both A and B

T: Compare these tension together which is bigger than the other between tension A and tension B?

L1: Tension object B

T: Who can answer this question?

L3: Tension object A

T: Raise your hand!

L2: Which one is bigger than the other?

T: Who can compare these tensional between A and B. What's happening here grade 11 work!

L1: Tension of A is greater than of B

T: That is not true

L2: They are equal

T: Why say equal? Tell me the law that says that all two are equal. Give me that law, is it first law or third law.

L2: It is third law?

T: Tensional A and B are equal, and in opposite direction according to the third law. It means if this one is positive then the other one is negative.

The lesson was teacher-centred with some active engagements of learners. It was mostly didactic with some open-ended discussions. In this lesson, the teacher was seen both as a facilitator and giver of knowledge. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents. The mean scores for the lesson on each category are displayed in table 5.12 below.

Table 5.12: Scale statistics for lesson 2 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	1.6	.49
Classroom discourse	2.4	.49
Assessment	2.4	.80
Curriculum	1.8	.83

The table above shows the average inquiry instruction score of 2.05 out of four on all the four categories. The overall score is *developing inquiry* stage, which is level two on the EQUIP four levels of inquiry. The teacher occasionally acted as a facilitator but it was for very brief moments.

After the lesson, I met with the teacher for the post-lesson interview. I commended the teacher for the good questioning skills and the use of simulation. We agreed to work on improving the curriculum and instructional factors, as shown in the following excerpt:

R: You are asking good questions.

T: I prefer getting all the important contributions from the learners.

R: You need to improve on the other factors like curriculum and instructional factors as in the EQUIP tool.

T: I am struggling to initiate learner to learner interactions, I still feel they are time consuming.

R: I think everything is time consuming when you start, but with time you will save more time as you perfect it.

T: In my next lesson I will involve learners more and support them in their discussions.

The teacher's questions remain largely closed questions. The most interesting thing is he believes in learner participation.

5.3.2.3 Lesson 3: Equilibrium constant (Grade 12)

The teacher prepared a model for calculating the equilibrium constant. The learners are seated and the teacher greets the class. He started by asking the learners what they understand by the equilibrium constant and the learners gave him the factors that affect the equilibrium constant and the formula for getting equilibrium constant. The teacher then told the class that he is going to show them how they will get the equilibrium concentrations that are needed to calculate the equilibrium constant. The teacher draws a model table with the various steps that learners are supposed to follow and use one example to show the steps. The teacher is worried about drilling the method into the learners so that when they have different questions in the exams they can still find the correct answers. He is doing much of the talking and asking questions. The majority of his questions are closed questions and the learners are responding fairly well. The excerpt below shows the interaction between the teacher and the learners:

T: Let's draw our table. So now you draw your table. When you calculate your Kc, you write your things, A, B, and C. After that what are you going to write in these?

L: RICE.

T: Are we all together. But you must know what that stands for. In 2014 they were crying when marking. Learners were just writing RICE but they don't know what it means.

T: What does ‘R’ stand for?

L: Ratio

T: Where do we get the ratio?

L: From the balanced equation

T: What is ‘I’?

L: Initial moles. It means you read the statement in order to get it. Are we all together?

L: Yes

T: What does ‘C’ stand for?

L: Change in moles.

T: What do you consider?

L: The balanced equation

T: What does ‘E’ stand for?

L: Equilibrium

T: In order to get the equilibrium mole you read the statement. You can get it in the statement. Or you add this initial and change. Are we all together. What does E stand for?

L: Equilibrium concentration.

The teacher gave them a question to attempt in groups and moved around checking the progress. He is at table one where the first group is seated. Here is an excerpt showing his interaction with the group members:

T: A question like this is usually seven marks. So are we going to go straight and calculate Kc or we are going to use the table?

L: We are going to use the table

T: Let’s start for step 1. Step one we go for the ratio. What is the ratio in the balanced equation?

L: 1:2:1

T: One mark. The balanced equation, is it difficult guys? It’s not difficult.

L: Yes.

T: For initial moles, you read the statements. 1 mole of A and 2 moles of B react in a $2dm^3$ container. It means initially those moles were ejected in the container. How many moles

L: 1 mole of A

T: What else is given?

L: Moles of B

T: Where?

L: Initially

T: Where do I put it?

L: Under 2

T: Yes. What were the initial moles of C?

L: Zero

T: Is it difficult?

L: No.

The teacher then gave a model answer of the table and learners were supposed to complete it using variables generated by the teacher to see if they have mastered the manipulation of the table. The following is the teacher's interaction with the whole class as he concludes the lesson.

T: And this one must be positive, positive what?

L: X

T: In order for you to get the equilibrium moles you must further read. They say if at equilibrium it means what is given belongs to what?

L: To Equilibrium

T: If at equilibrium 0.75 moles of C has formed. Where must we put 0.75?

L: Under X

T: What else is given, what volume is given?

L: 2 dm^3

T: Do we need to convert?

L: No

T: Usually we first find x. if you find x, use the one that you have at equilibrium. Which one do you have at equilibrium, A, B or C. which one are we going to use to find our X?

L: C

T: How did we arrive at the moles at equilibrium?

L: We add

L2: Initial moles plus x

T: It means they have added x to zero. X is equal to 0.75. After finding x where ever you have x you must put 0.75. Do we understand guys? You get these values of x you get another mark. How many marks are we having now?

L: Two marks

T: How are we going to have the moles at equilibrium for the other reactants?

L: Initial plus change

T: By getting these values, you get a mark. How many marks are you now having? Is it difficult guys?

L: No

T: How do you arrive at concentration? To calculate concentration at equilibrium we say c=n/v where n is the number of moles at equilibrium. And v is the volume of the container. How much was the number of moles at equilibrium here?

L: n-x

So it's going to n-x divide by. What is the volume?

L: v

How much is the concentration at equilibrium here?

L: y-3x/v

How much is the concentration at equilibrium here?

L: 2x/v

The lesson was teacher-centred with some active engagement of learners. The teacher was mainly working in front of the class and predominantly at the centre of the lesson. The purpose of the lesson activities was to drill and practice. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom.

Each category was then scored according to the following table, on the level of inquiry it represents. The mean scores for the lesson on each category are displayed in table 5.13 below.

Table 5.13: Scale statistics for lesson 3 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	1.6	.80
Classroom discourse	2.0	.00
Assessment	2.4	.49
Curriculum	2.0	.82

The table above shows an average inquiry instruction score of 2.00 out of four on all the four categories. The overall score depicts a *developing inquiry* stage on the EQUIP levels of inquiry. This lesson was now showing some improvement in the curriculum factors and a drop in the classroom discourse.

During the post-lesson interview the researcher highlighted the need to involve learners in investigations. The excerpt below is the evidence of the interaction between the teacher and the researcher.

> R: Your curriculum has improved. I find that you ask many questions during the lesson, but activities are equally important.
>
> T: I strongly agree with you, though the topics does not have much experiments.
>
> R: How about simple reactions with colour changes like cobalt chloride experiment.
>
> T: You know my problem with chemistry, some of those chemicals could be expired. I don't have time to test them.
>
> R: One experiment will not take as much time.
>
> T: I will do that with the lower grades, the grade 12 are behind with the syllabus and are writing a common test.

The teacher promised to include investigations when teaching grade 10 and 11. When asked if he is not doing any investigations with the grade 12, the teacher mentioned that only School-Based Assessment (SBA) experiment. A SBA is a school-based activity that contributes up to 25% of the learner's summative assessment mark.

5.3.2.4 Lesson 4: Le Chatelier's principle -concentration and temperature (Grade 12)

The teacher is getting the laboratory ready for a short movie. He has prepared three video clips to show. The first one is a video of children playing on a see-saw, the second one is a dynamic step (escalator) and the third one shows how cobalt chloride changes colour in the warm and cold water. The teacher invited the learners to watch the videos and write down their observations. The teacher then asked questions based on the learner's observations; and leading to the concept of reversible reactions favouring one side at times and getting to equilibrium sometimes. The teacher explained the Le Chatelier principle:

> T: Le Chatelier says, when the equilibrium in a closed system is disturbed, Esona has disturbed the equilibrium because this see-saw is straight. Now the equilibrium is disturbed. Now if the equilibrium is disturbed the system will reinstate the new equilibrium. When you reinstate you are taking it back to the equilibrium; by favoring the reaction that will oppose the disturbance
>
> L: Sibongile
>
> T: It means we add more 'Sibongiles' on that side in order to take Esona up. Are we all together. If you increase reactant automatically products will increase and reactants will decrease. If you decrease reactants the reactants will increase and the products will decrease. Le Chatelier will always oppose what is happening. Le Chatelier will always make sure the reaction is at equilibrium. Let's apply Le Chatelier's principle now.

The teacher explains the principle using an example from a past examination question paper. Below is the excerpt from the teacher interaction with the class:

> T: Let me explain first you know when I explain something I want to use the examination question paper to explain the way question is asked in the exam.
>
> $$A (g) + B (g) = C (g) + D (g)$$
>
> If more A is added, in other words, they are trying to say. The concentration of A was increased. If more of B was added, what are they trying to say?
>
> L: Concentration of B was increased.
>
> T: If they say A was removed, they are trying to say the concentration of A was decreased. If they say B was removed they are trying to say the concentration of B was decreased. If C were added it means the concentration of C was increased. Let's start from the first one. Number 1, this is four marks, Le Chatelier's principle. Why the concentration of A is increased, A will be followed by a gradual decrease in A, and that will cause a decrease in B. This is the first point I mark. The second point which is the 2nd mark, the equilibrium position will shift to the right or left?
>
> L: To the right.
>
> T: Which reactions are favoured, number 3. If we say the position will shift to the right is the forward or reverse reaction favoured?
>
> L: Forward reaction is favored

T: Then you say forward reaction is favoured. 3 marks. Is it difficult? If the forward reaction is favoured what will happen to the yield of C and D.

L: It will increase

T: I repeat, more A was added, use Le Chatelier's principle to explain what will happen to A. What are you going to explain first? The concentration of A and B will decrease, 1 mark, and second is about the equilibrium position (does it shift to the left or to the right). We don't say the equilibrium will shift to the right, but equilibrium position. If equilibrium shift to the right it means forward or reverse is favoured?

L: Forward

T: If forward is favoured does the yield increase? If forward, are we going to yield more products or fewer products?

L: Less product (in a chorus)

T: More products. How can you say forward is favoured and it means more C and D is formed? Now let's come back. I will use A only so that you understand this. If A is removed I am trying to say the concentration of A was decreased.

The teacher had to revisit the same question to make the learners understand why the yield was increased. He used different examples to explain why the yield increased. The teacher then realized the learners did not understand the term yield. When everyone was now in agreement the teacher asked the learners to take notes on how temperature increase and decrease affected the equilibrium position:

T: Can we write it down? You have to memorize this. (1) Increase in temperature favours endothermic reaction. (2) The decrease in temperature favours exothermic reaction. Guys, do you know why the increase in temperature favours endothermic? If endothermic is taking in temperature, it means the temperature of the reaction is decreasing. Guys, when I was explaining at SSIP those who were at SSIP, do you still remember the table. What did I say to you?

L: You said it is exothermic when the temperature is increasing.

T: If the temperature is decreasing it is endothermic. So we said Le Chatelier is opposing, in endothermic temperature is decreasing, Le Chatelier says it must increase. In exothermic, the temperature is increasing so Le Chartier says it will decrease.

L: Like Jamal

T: Yes, he was not completing his degree programs.

The teacher then gave them a question to work on. The teacher then led the discussion of the solution:

T: Let me write my reaction which is interesting

$$C + O_2 = CO_2 + heat$$

This reaction, I have taken coal and burn it. It's what you are doing at home when you are cooking. Tell us what will happen to the yield of CO_2 if I increase temperature. (4) Marks

L: It will increase.

T: How did you answer your question here? You must have four bullets. The first bullet identifies if the forward reaction is exothermic or endothermic. Let's say it was reversible - is it exothermic or endothermic?

L: Exothermic

T: + heat means it's exothermic. What do you write first, the forward reaction is exothermic? You get a full mark because the learner was able to identify that the reaction is exothermic. Second they said if you increase temperature, you check the question it is asking – increase in temperature. According to Le Chatelier, the temperature favours which reaction?

L: Favours endothermic reaction.

T: Then you write your increase in temperature favours endothermic, then you get a mark, you see you already have two marks. You have used the reaction and the question. There is no thinking here. Did you even think there?

L: No

T: Then the third point, you are going to say in the third point: Which reaction is going to be favoured here? Is it reverse or forward?

L: Reverse.

T: Then you write here reverse reaction is favoured. You get a mark. Is it difficult this thing? It needs you to understand the statement when the statement is put in front of you. But we will do many questions so that you may understand. Just relax, I will give you many copies of the questions, I have many question papers, to fill up your book. The last question we are going to shift to which side, left or right?

L: To the left.

T: Therefore is the yield going to increase or decrease? The answer is obvious.

L: Decrease obvious

T: It has shifted to the opposite side and once it shifted to the opposite side it means what is on the right will suffer. I want to give you another question on temperature.

The learners are complaining about the number of questions they have attempted in one lesson. The teacher then tries to convince them that it is the last question for the day. The teacher indicates to the learners that the kind of question he wants to do is similar to the one they are set in their coming June exam. All the learners now are listening attentively:

> T: Esona do you know which one is going to be in the exam? The one I want to explain is the one that will be in your exam paper. This one I am going to write it down and explain. Do you still remember that here I was not explaining when we were doing the concentration question, do you still remember. Do you know why I was not explaining?
>
> L: No
>
> T: Because I know they will never ask such a question with A and B, but this one they will ask. Can we listen? Is this equation balanced?
>
> L: Yes
>
> T: Make sure guys when you explain you explain in a balanced equation. What do you call this reaction, when you add an alkane and oxygen, what will be the product.
>
> L: Combustion
>
> T: What are the products?
>
> L: CO_2 and water

The lesson was teacher-centred with some active engagement of learners. The teacher was mainly working in front of the class and predominantly at the centre of the lesson. The purpose of the lesson activities was to drill and practice. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents. The mean scores for the lesson on each category are displayed in table 5.14 below.

Table 5.14: Scale statistics for lesson 4 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	1.8	.74
Classroom discourse	2.4	.49
Assessment	2.4	.49
Curriculum	2.0	.82

The table above shows an average inquiry instruction score of 2.15 out of four on all the four categories. The overall score depicts a *developing inquiry* stage on the EQUIP levels of inquiry. This lesson was now showing some improvement in the instructional factors and classroom discourse. When asked during the post-lesson interview why he is not making an effort to include activities during his teaching of the grade 12, he mentioned that he prefer using examination questions.

5.3.2.5 Lesson 5: Le Chatelier's principle –pressure (grade 12)

The teacher starts by giving the model of explanation that is expected when explaining the effect of pressure on the equilibrium position. He asked the learners to take down the notes on the two important effects of pressure on equilibrium position and used examples to explain the notes. The extract below shows the two bullets of the notes given and the learners were supposed to use the notes to answer questions on pressure:

> T: Let's talk about pressure. Guys the pressure, what is important about pressure? Increase in pressure favours the reaction that forms number of moles. Wait, the increase in pressure favours a reaction that forms less number of moles. The decrease in pressure favours the reaction that forms more numbers of moles.

The teacher compares the explanation for concentration to that of temperature and contrasts the explanation with that of pressure. He emphasized the importance of looking at a balanced equation and making sure the chemical equation is balanced. The learners were expected to only count the number of moles of gases on each side of the chemical equation and decide which side had more. The learners were also told to ignore anything which was not in the gaseous phase. When the teacher was asked after the lesson why he prefers to tell the learners everything, he said he felt his learners were not doing any extra work besides what they do in class. The following excerpt is the discussion between the teacher and one of the groups in the classroom:

> T: How many numbers of moles are here?
>
> L: One
>
> T: Here?
>
> L: Two
>
> T: In total it's?
>
> L: Three moles
>
> T: Three moles means three volumes. How many moles are here (this side of the reaction?)
>
> L: Three
>
> T: Increase in pressure favours the reaction that forms less number of moles. Is there a side with less number of moles here?
>
> L: No
>
> T: Forward is forming 3 and reverse is forming 3. The decrease in pressure favours the reaction that forms more number of moles. Is there a reaction that forms more number of moles here?
>
> L: No
>
> T: I will write the equation here so that you can try to understand them. Let me ask you something here if pressure is increased here. Do you think the amount of CO_2 will increase or decrease?
>
> L: It remains the same.
>
> T: Remain the same, why?
>
> L: Because forward reaction forms 3 moles and reverse reaction forms 3 moles. Therefore an increase in pressure favours the reaction that has less number of moles, so there is no reaction that is favoured.

The teacher then moves to the next group as the learners are busy with the exercise that he gave from the textbook. This group was already working on the second question. Here we see the teacher asking a more open question an improvement from his previous interaction with the learners of the previous group:

T: What will happen to the yield of SO_3

L: It will increase.

T: It will decrease. Then now if you increase the pressure, what will happen? You are working for 4 marks. What are you going to say?

L: Increase in pressure favours the reaction that forms less number of moles.

T: One mark. Are we all together? Therefore which reaction here forms less number of moles? Is it a forward reaction or reverse reaction?

L: Forward.

T: So you say forward reaction is favoured. If forward reaction is favoured, does the equilibrium position shift to the left or right?

L: Right

T: Is more of this formed or not?

L: More SO_3 is formed, therefore it increases.

T: So the application of Le Chatelier's principle we are done with. So let's answer these questions.

The teacher then asked the learners in their groups to come and present the answers to their questions as evidence that they could fully follow the model answer taught. The following excerpt is the presentation by group three. This seemed to be a group that had learners who were participating actively in the lesson. Following each other, in a sequence, each one gives the answer:

T: State what will happen to the yield of ammonia, if more nitrogen is added to the reaction. Identify the factor we are looking at first?

L1: Concentration.

L2: The concentration of N_2 and H_2 will decrease

L3: Forward reaction is favoured.

L4: Equilibrium position will shift to the right.

L5: More NH_3 will be formed so NH_3 will be increased.

T: Here you have 4 marks.

The teacher continues to ask the questions and the groups were presenting in a sequence with each group member contributing. A total of seven groups presented their answers and the teacher was satisfied the learners were now confident in the concept. The rest of the group's presentations are captured on the lesson transcript.

The lesson was teacher-centred with some active engagement of learners, prescriptive but not entirely. The teacher was mainly working in front of the class and predominantly at the centre of the lesson. The purpose of the lesson activities was to drill and practice. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents. The mean scores for the lesson on each category are displayed in table 5.15 below.

Table 5.15: Scale statistics for lesson 5 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.0	.89
Classroom discourse	2.4	.80
Assessment	2.6	.80
Curriculum	2.0	.82

The table above shows an average inquiry instruction score of 2.25 out of four on all the four categories. The overall score depicts a *developing inquiry* stage on the EQUIP levels of inquiry. This lesson was now showing some improvement in the instructional factors and assessment factors. The change is minimal and the evaluator discussed the way forward with the teacher. The teacher promised to integrate investigations in his teaching.

> R: I need to observe the lower grades.
>
> T: I am having the grade 10 class. I will re-do the electricity lesson. You can come and observe that.
>
> R: What is your plan for improving instructional factors?
>
> T: I have planned lessons with at least one activity. The coming one is electricity and I can do many activities.

The teacher is now overcoming the fear that activities are time consuming. He is willing to do more activities and is convinced they may make learners understand Physical Sciences better.

5.3.2.6 Lesson 6: Electricity (grade 10)

In this lesson Mr. Kapok prepared to deliver a lesson on electric circuits. A post-lesson interview between the researcher and the teacher had concluded that it would be proper if the teacher could repeat his previous lesson on electric circuits. The teacher wanted the learners to explore the concepts current, voltage and resistance. The main objective of the lesson was to allow learners to observe, record, analyse and draw circuit diagrams. The learners were supposed to distinguish between potential difference and electromotive force. The teacher started the lesson by asking learners to identify the apparatus that he was having on his front desk. The learners were eager to learn, the moment they saw laboratory equipment they showed an interest. The learners knew the majority of the equipment except a few, where they were confusing the name of the equipment and what it measures. The excerpt below is the evidence of the teacher assessing the learner prior knowledge:

T: What is this?

L: It's a circuit board

T: What is this?

L1: Battery

T: No

L2: A Cell

T: This is a cell, it's not a battery. A battery is a combination of two or more cells that are connected its series or parallel, its only one cell.

The teacher managed to ask open questions, although most of the time he ended up giving the full explanation. The learners were responding well to the questions but in a didactic manner. The learner-to-learner interaction was minimal, with most of the questions and probes from the teacher. The following excerpt is evidence of teacher-learner interaction:

T: This an ammeter, what is the use of an ammeter?

L: It is used to measure electric current

T: Do you connect it in series or parallel?

L: Series

T: How do you connect this voltmeter in parallel or in series?

L: Parallel

T: Why do we connect it in parallel?

L: Because it has a high resistance? [*In a chorus*].

T: But for ammeter, this resistance here is too small such that it may not have any effect on the current that is flowing through the circuit. Are we all together?

The teacher then called everyone in front to observe while he was building a circuit. He demonstrates to the learners how each of the components is connected. The excerpt below is the evidence of the teacher demonstration on how to create a circuit and to measure voltage and current using the voltmeter and ammeter:

T: Here's my circuit board, here is my bulb, and I connect my bulb. I connect my switch, what is this?

L: A cell holder

T: A cell holder. What are we going to make? We are going to make a battery, remember in a cell there are two terminals what do you call those terminals?

L: Positive and negative terminals

T: Which one is a positive terminal and which one is a negative terminal? We have the one with the short rod and one with a long rod

L: The one with a long rod is the positive and the short rod is negative

T: Yes the black one represents negative. Here you connect the red one. What is the reading here?

L: 6, 2 Volts

T: V = 6, 2 let's switch on the switch

T: Now what is happening to my voltmeter - is it increasing or decreasing?

L: It's decreasing, what is the voltage?

L: 4, 6 volts

L2: 4, 9 volts

The lesson was teacher-centred with some active engagement of learners. The teacher managed to capture learner attention by the presence and use of apparatus. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents. The mean scores for the lesson on each category are displayed in table 5.16 below.

Table 5.16: Scale statistics for lesson 6 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.0	.00
Classroom discourse	2.6	.00
Assessment	2.6	.49
Curriculum	2.0	.70

The table above shows an average inquiry instruction score of 2.3 out of four on all the four categories. The overall score depicts a *developing inquiry* stage on the EQUIP levels of inquiry. I met with the teacher for the post-lesson interview and we discussed all the categories. I commended the teacher for including an investigation. We agreed to work on improving the instructional factors, as shown in the following excerpt:

> R: A good lesson, just needed more time.
>
> T: Yes our lessons are too short for science activities. I will reduce the talking and give them more time to engage in the activities.
>
> R: That will be great. Did you see how they enjoyed the last part of the lesson?
>
> T: Yes. The activities can be the way to capture their interest.

The teacher had included the activity, but could not finish in time. The class was actively involved especially during the demonstration.

5.3.2.7 Lesson 7: Acids and bases (Grade 12)

The teacher starts the lesson by reminding the learners that the topic is the last topic for the term and for the year they are left with three topics. The teacher mentions the topics left, which are Electric circuits, Electrochemical cells and the Photoelectric effect. The teacher then informed the learners that the present topic has a total of 22 marks in their final exam. He even indicated that in their June exam it’s going to be

40 marks or 30 marks. In addition to that, he told them that Acids and bases is one of the easiest topics. He asked one learner how to identify an acid from their grade 9 knowledge and how to distinguish between acids and bases from grade 11. The following excerpt is the interaction between the teacher and the learners as he sought to ascertain their prior knowledge:

> T: How do you identify an acid or base?
>
> L: From the properties
>
> T: Yes, aim to talk about those properties from grade 9 - the simplest ones
>
> L: Bases are sour
>
> T: I have to correct you. Bases are bitter, acids are sour, and if it is sour it is acids. We have these acids in our everyday lives so now we are going to start with these are two definitions we are going to look at [*looking for his notebook*]
>
> T: Give me the definitions of acids according to Arrhenius. Close your books
>
> L2: A substance that forms hydrogen ions in water.
>
> T: Let me just come in there, an acid is a substance that forms hydrogen ions or hydronium ions when dissolved in water. Hydrochloric acid must form H_3O^+ ions, it means this H+ has left Cl- to form H_3O^+ in aqueous. How can you tell that it is an acid? It is an acid because it has formed H_3O^+ when dissolved in water
>
> T: What is a base according to Arrhenius?
>
> L: A base is a substance that forms hydroxide in water
>
> T: I want to give these definitions; these definitions are in your exam guidelines. I don't have time to write. She is saying according to Arrhenius, he defines a base as a substance that forms hydroxide ions when dissolved in water. For example let's take the common base the one which is formed in the Haber process, which is ammonia.

The teacher then informed the learners that they were going to have a practical to determine the concentration of an unknown acid using titration. The learners are given the instruction sheet and are arranged in groups of eight. Each group is given a table to work on and the materials to use. The learners have their sodium hydroxide as the titrant and oxalic acid as the analyte. The learners are familiar with neutralization reaction from grade 11 and know the products are salt and water. In this case, they may not know the salt formed. When the teacher was asked about the background knowledge about titration, he indicated they had done some titration when the learners were in grade 11 although it was not an accurate one. The learners are excited to see a colour change at the end point. All the groups collected their chemicals and the teacher is ready to give any assistance needed. The teacher highlighted the precautions and the learners are given a go-ahead to start their titration. The following is a conversation between learners in one group:

> L1: What are we doing?
> L2: We must add sodium hydroxide in the burette.
> L3: How much are we adding in the burette?
> L1: Is it not 25 ml?
> L4: No, 25ml is for the acid, in a conical flask right.
> L2: Do we need water?
> L3: We need phenolphthalein indicator
> L2: Okay for colour.

The teacher is seated on his desk where he was issuing chemicals, observing the learners as they plan their titration. He then went to the group that was closest to his table to see the progress. He looks at the learners as they do the titration and then makes his contribution after they get their first titer value. The following excerpt is the conversation that the teacher had with the group members of the first group he visited:

> T: I noticed your funnel is still on the burette while you are performing your titration
> L1: Yes, we are going to use it to transfer more sodium hydroxide.
> T: Don't you think it must be removed from the burette?
> L2: Yes. I think sir is right.
> L3: I think it blocking the movement of the liquid when you open the tape.
> T: That's not important, pull it up and see what is actually happening.
> L4: it still has some liquid around it.
> T: What does that mean?
> L1: Our volume may not be correct.

The teacher asked the group to proceed and do the second titration. The teacher moved to the second group and the learners seemed to be discouraged. The teacher asked what was the problem, the leaners had added all the sodium hydroxide and there was no colour change. The following excerpt is the interaction between the teacher and the learners in the group:

L1: We have added all the base and we don't see a colour change.

T: Which colour are you expecting?

L2: Pink

T: Where is the colour coming from?

L3: From the end point

T: What is changing colour, if I may ask?

L4: The indicator sir, we did not add the drops of the indicator. Thank you, sir.

The teacher rotated all the groups attending to the procedural issues. When all the learners had completed their three accurate titrations, the teacher asked them to calculate the average volume of sodium hydroxide. The teacher alluded to the fact that some learner's results were not accurate as they had errors in reading the volume and passing the endpoint. The teacher then asked the group that had the best results to show the others the expected colour and share how they managed to get good results. They used their results to then calculate the concentration of the oxalic acid.

Mr. Kapok frequently acted as a facilitator in this lesson. His learners were consistently and effectively active as learners throughout the lesson. The learners are seen to be actively engaged in activities with evidence of exploration. The learners often followed up responses with an engaging probe that required the learner to justify reasoning. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.17: Scale statistics for lesson 7 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	3.4	.49
Classroom discourse	3.0	.00
Assessment	3.2	.40
Curriculum	2.4	1.00

The table above shows an average inquiry instruction score of 3.00 out of four on the mean score of all the four categories. The overall score shows that the *Proficient inquiry* was realized as explained in the EQUIP tool. This lesson showed an improvement in all the categories. The post-lesson interview with the teacher was on ways to improve the curriculum factors. The evaluator commended the teacher on the great improvement on the instructional factors. Among other things the teacher mentioned the pressure of summative assessment as one of the challenges they are facing in inquiry-based teaching. The following excerpt is the evidence;

> R: This was a great success, what did you do differently today?
>
> T: I now understand that time management is important and learners need support throughout the investigation.
>
> R: I find that you always refer to the exam question paper and the number of marks when you teach.
>
> T: These learners need constant reminder about their exams. We are actually preparing them for external examinations. I can say my teaching is exam driven.

The teacher always refers to the exam and constantly remind the learners about the examinations. The investigations that contributed to the summative assessment mark were highly regarded in his classroom.

5.3.2.8 Lesson 8: Electricity (grade 10)

The learners enter the laboratory in a rush as the teacher is already waiting for them. The tables are arranged into eight working stations. The learners arranged themselves to fit at the working stations. The teacher greets the class and asks them why they did not come early when they were aware that they are having an experiment. The learners told the teacher that they were delayed by the other teacher, who finished late. The teacher then went straight into the business of the day. The excerpt below is the teacher's interaction with the class as a whole before they started to work in groups:

T: We have circuit boards on the table, connecting wires and four cells. Here are worksheets that have the diagrams of the circuits that you must build and measure the voltage and current. Each learner must record the reading on their worksheet and write the names of all the group members. You must be fast.

L: When are we submitting, sir?

T: Today, you know this? We have done circuits in class before.

The learners collected their worksheets and started their experiment. There was clapping of hands at one group and the teacher went to the group to witness the occasion. The learners had successfully built a circuit and their bulbs are glowing. The following excerpt is the conversation between the teacher and in of the learners in that group:

T: Why is everyone happy in this group?

L: We managed after a struggle to come up with our circuit for parallel resistors.

T: What was the main problem and how did you solve it.

L: We did not know how the ammeter and voltmeter are connected.

T: What happened?

L: We did our research and now it's working.

T: How then do you connect the voltmeter and ammeter?

L: One must be in parallel while one is in series.

T: Which one is in parallel?

L: Voltmeter

L2: Sir, why is the voltmeter not connected in series?

L3: It has high resistance, and current won't pass.

The teacher visited the next group. They already had readings for the series connection. The teacher asked the learners of their conclusion from the results. The following is the interaction between the teacher and the learners:

T: What do the results tell you about the resistors in series?

L1: If we measure the current it does not change.

T: Okay, what about the voltage?

L2: The voltage is not the same it's changing.

T: What do you mean, use V_1, V_2, $V_{3,}$ and V_{total}?

L3: v1 and v2 are different.

T: Did you try to add them? Try it.

L4: They give us v3.

T: What does it mean?

The teacher goes to the next group that had connected well but were struggling with understanding why their voltage was not changing. They thought the voltmeter was not working. The teacher asked them to measure current and they did. The following excerpt is the evidence of the interaction between the teacher and the group members:

L: I think our voltmeter is faulty.

T: Why?

L: The voltmeter reading at all the points is the same.

T: Is that the only problem? Can you measure current?

L: We did

T: And what is the current?

L: Its fine, it's changing.

T: Look here, if we add this one and this one what does it give us?

L: I can see, current is dividing. It means the voltage must be the same.

T: Which connection is that?

L: Parallel connection.

The teachers asked the learners to complete the task in the remaining time and submit their papers. In this particular lesson, Mr. Kapok occasionally lectured. His learners were consistently and effectively active as learners throughout the lesson. The teacher often followed-up responses with an engaging probe that required the learner to justify reasoning. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.18: Scale statistics for lesson 8 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	3.6	.49
Classroom discourse	3.0	.63
Assessment	3.0	.00
Curriculum	3.25	1.30

The table above shows an average inquiry instruction score of 3.21 out of four on the mean score of all the four categories. The overall score shows that the *Proficient inquiry* stage on the EQUIP levels of inquiry was realized. This lesson showed an improvement in all the categories. The post-lesson interview had a review of the lessons from the first lesson on electricity to the current lesson. The teacher overcame the scare of enacting inquiry in his classroom and acknowledged he benefited from the experience. The excerpt below is the discussion between the evaluator and the teacher.

> R: What can you say about the progress so far?
>
> T: I know good teaching is through discovery, but township schools are facing many challenges. Instead of a teacher focusing on teaching, time is lost on other things. We must protect contact time. If all things are equal inquiry is a good method for teaching science.
>
> R: Can I conclude that the experience was worthwhile?
>
> T: Yes. I have benefitted from the experience. The discussions after the lessons were helpful. I still want to try it with the grade 12. I have no problems with other grades, but I think it will work.

Mr. Kapok has increased understanding of inquiry, although he is still hesitant to fully include investigations in the teaching of the grade 12.

5.3.2.9 Cumulative summative percentage inquiry scores per lesson

The section presents a summary of the quantitative data generated from the EQUIP from the eight lessons observed. Each of the categories are presented from lesson one to lesson eight. The last column shows the percentage inquiry per lesson, which gives a snap shot of the trend from lesson one to eight. The percentage inquiry per lesson was calculated from the total scores of the four indicators expressed as a percentage of the possible score. Thus, the comprehensive total scores was then divided by the possible score (16) and multiplied by 100 to get percentage inquiry per lesson.

Table 5.19: Percentage inquiry in different lessons comprehensive score per category

Lesson number	Instructional factors (4)	Classroom discourse (4)	Assessment (4)	Curriculum (4)	Comprehensive total score (16)	Percentage Inquiry per lesson (100)
1	2.0	2.6	2.4	2.3	9.30	58.13
2	1.6	2.4	2.4	1.8	8.20	51.25
3	1.6	2.0	2.4	2.0	8.00	50.00
4	1.8	2.4	2.4	2.0	8.60	53.75
5	2.0	2.4	2.6	2.0	9.00	56.25
6	2.0	2.6	2.6	2.0	9.2	57.50
7	3.4	3.0	3.2	2.4	12.00	75.00
8	3.6	3.0	3.0	3.25	12.85	80.31

5.3.2.10 Mr. Kapok summary

The teacher's overall inquiry instructional practice was scored based on the four categories as depicted on each lesson EQUIP tool; instructional factors, discourse factors, assessment factors, and curriculum factors. In the first six lessons the teacher predominantly at the centre of the lesson. The learners were not engaged in any exploration and any meaningful learner to learner interaction. The lessons were teacher-centred but with some active engagement of learners. His lesson was still prescriptive but not in everything and all six qualified as *developing inquiry*. Mr. Kapok struggled with incorporating investigations in his lessons. In lesson seven and eight there was a drastic improvement in his approach as he started to incorporate investigations. The teacher began to probe the learners. The teacher finally managed to achieve *proficient inquiry* in lesson seven and eight. The learners were engaged at all stages of the lesson including giving explanations. The shift in the teacher's practice was minimal as the teacher was not incorporating investigations in his teaching. Several interviews were held with the teacher and the teacher would choose to use the inquiry related questions to teach science practices.

5.3.3 Mr. Moloku

The section presents eight lesson observations for Mr. Moloku together with their EQUIP scores. Each lesson is a vignette and a thick description of what transpired in the lesson was given leading to an evaluation of the lesson in terms of the level of inquiry according to the EQUIP levels of inquiry.

5.3.3.1 Lesson 1: Collinear vectors (Grade 11)

The teacher had prepared a lesson on the calculation of the resultant vector for both collinear and non-collinear vectors. This was the first lesson to be observed by the evaluator and was used as a baseline lesson observation. This was before the evaluator had a meeting with the teacher on the goals of inquiry-based teaching.
The class arrives and stands at the door waiting for the teacher to come and mark the register. The teacher meets them at the door and asks the names of the learners

absent that day. After marking the register the teacher asks the learners to come into the laboratory. A class of energetic grade 11 learners entered and stood by their tables waiting for their teacher to greet and ask them to take their seats. They sit and the teacher starts the lesson by drawing a number of vectors on the Cartesian plane and asks the learner to identify vectors in the same direction. The learners identified two pairs of vectors F_2 and F_4 and F_1 and F_3. The teacher emphasized the fact that F_1 and F_2 are in the same direction and parallel, but F_1 and F_3 are parallel and in opposite direction. He explained that for vectors to be either in same direction or opposite direction they must be parallel. Such vectors that are either in the same direction or in opposite direction are referred to as collinear vectors. The teacher writes the topic on the chalkboard and looks back and says "it's today's work", and his learners open their books and start writing. He then writes the definition of collinear vectors on the whiteboard. The teacher shows the class how to get the resultant vector if the vectors are not collinear. He uses vectors F_2 and F_4. He moved F_2 from where it was and brought it before vector F_4. He then explained how to calculate the magnitude of the resultant vector. The teacher interacted with the class on how to calculate the magnitude of the resultant vector. The excerpt below is his exchange with one of the learners:

T: What is a resultant vector?

L1*:* A vector that replaces all the vector acting on an object.

[The teacher writes the learner's response on the whiteboard and makes a comment. "You are not going to write this."]

T: What is their magnitude?

L2:12

T: How did you get the 12?

L2: We have added

T: How fully can you describe that vector?

[*The teacher explains how it becomes 12N. "Where F2 start I draw a vector up to where F4 ends".]*

The teacher repeats the same calculation and explanation using vectors F1 and F3. After writing the answer, one learner asked a question. Here we see another exchange when a learner needs clarification on the negative sign:

L: I thought you can’t have a resultant force as negative.

T: I don’t know what you mean. As force is a vector it will have a magnitude and direction. If it is in that direction I call negative then it’s negative.

L: Like we were told that we can’t give the final answer as negative.

T: Now I get what you are saying if it’s a calculation and your final answer is negative you have to give the meaning of that negative, we know what our negative means, its 2N downwards.

There was a moment when the teacher could probe the learners so as to extract the answers from them. The excerpt below is an example of such interaction:

T: Can you give me an example where it is applied in real life?

[Mr. *Moloku asked as he moved closer to the learners*.]

L: When you are pushing a car uphill.

L: You are applying a force to the car and the car due to gravity is applying a force on you.

T: You will learn about it later. What about any closer examples?

L: When you drop something.

L: I see you often, two boys or two girls fighting for a chair, one is grabbing it this way and another grabbing it that way.

L: Tug of war.

T: That is a good example. Tug of war, we have two groups pulling in different directions. I gave an example of two boys fighting for a chair. They are exerting forces in opposite direction. If they are exactly in the same direction it’s either the chair remains on the same position or one is pulled. Depending on their forces. If it so happens that they are not pulling in opposite directions, what do you think will happen. Here is the chair, one is pulling up and the other one sideways.

L: It will go to the one who is applying the bigger force.

The teacher proceeded to the resultant of vectors, which are perpendicular. He did examples of the calculations on the whiteboard and the learners were responding to questions when asked. There was the application of the mathematical concepts and the learners were participating all the way. The teacher then concludes with giving homework. The learners were never given an opportunity to explore and the questions were merely to confirm content knowledge.

The first lesson was teacher-centred, in which learners were limited only to short answers and were not given an opportunity to explain and discuss concepts. In this lesson, the teacher was mainly working in front of the class and predominantly at the centre of the lesson. The lesson was further analysed using the inquiry lesson observation tool that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. The tool has four basic categories: instructional factors, discourse factors, assessment factors and curriculum factors. The summative overview on the tool provides the mean score on the level of inquiry demonstrated by the different constructs under each category, sliding on a Likert scale from 1 to 4. Each category was then scored according to the following table, Table 5.20.

Table 5.20: Scale statistics for lesson 1 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.4	.49
Classroom discourse	1.8	.47
Assessment	2.4	.49
Curriculum	2.5	.40

The table above shows the average inquiry instruction score of 2.28 out of four on all the four categories. The overall score is *developing inquiry* stage, which is level two on the EQUIP four levels of inquiry. This lesson was teacher-centred but did show some signs of inquiry on classroom discourse factors. The teacher occasionally acted as a facilitator but it was for very brief moments. In the post-lesson interview, the evaluator highlighted the need to utilize questions in supporting learner understanding of concepts and clear misconceptions. The teacher agreed to the vast opportunities brought in by experimental work and proposed an experiment in their next lesson.

5.3.3.2 Lesson 2: Resultant vector (grade 11)

In this lesson Mr. Moloku prepared to deliver a lesson on vectors. The lesson comes after the meeting on goal setting where the teacher and the evaluator came up with the specific goals for inquiry-based teaching for the particular teacher. A post-lesson interview between the evaluator and the teacher had concluded that it would be proper for Mr. Moloku to repeat the lesson on collinear vectors in form of a practical investigation. The teacher had gone through a brainstorming exercise with the evaluator on goals of inquiry-based teaching and had come up with his own personal goals. The teacher wanted the learners to explore the concepts using force boards. The main objective of the lesson was to allow learners to manipulate force meters, observe, record, draw force diagrams and calculate the resultant vectors. The learners came into the laboratory where the teacher had already set up five tables. Each table had a force board, rubber bands, a white paper and force meters. The instructions were written on the whiteboard and each group was given time to arrange equipment as was shown on the diagram on the whiteboard. The learners were working in groups of six and were supposed to repeat the experiment three times using different forces. The learners were working in their groups and the teacher was moving from one group to another. The following is the exchange between the teacher and one of the groups:

> T: Is it to the right or Left.
>
> L: It is to the right
>
> T: I am now emphasizing this so that you will be able to draw the diagram. Let's find Fy.
>
> L: -1.4N
>
> T: Is this up or down
>
> L: Downward
>
> T: It means 1, 4 N downwards. Who can show us the resultant in a different colour?

[*One of the learners in the group draws the resultant on the white paper*.]

The teacher is having an opportunity to elicit learner ideas and probe more to allow the development of scientific ideas. The teacher, instead of telling the learners that it means 1.4 downwards, could have asked them why the learner said downwards. The teacher could ascertain if the learner was guessing or understood the concept of a vector being a quantity with magnitude and direction. The probing can even allow others learners to ask their own questions and thus creating opportunities to clear learner misconceptions. In the excerpt below the teacher also was presented with an opportunity to ask the learners about a concept that he had taught before. Instead of the teacher asking the learners what he had said, he decided to tell them what he had said:

T: What do you say about the resultant? Is it fine?

L: Yes

T: Which one becomes the tail, which one becomes the head?

L: The tail of the resultant must be at the head of the last vector.

T: I didn't say that. I said the tail that is not joined. On the diagram the red one, two is a tail that is joined, and the head that is not joined. I actually used the word lose from the loose tail to the loose head. It means this is the resultant.

The teacher seems to be racing against time or driving learners to a certain objective that must be met within the time of the lesson. The use of questions should be developed and the ability to challenge the learner to explain, reason and justify. The teacher moves on to the next group that seems to be in the right direction. The following excerpt is the evidence of the interaction between the teacher and the learners in the group:

T: If you look at it logically a force is pushing to the right, which on other one is downward, how does it go up? There is an expression of R I gave you yesterday. R = square root of …

[*Learners are quiet. The learners check in their notebook and shout the answer*.]

L: $R_y^2 + R_x^2$

T: Which one is R_x and which one is R_y. What did you get?

L: 2, 69

T: What are these? Newton's. How many decimals should we round off to unless stated otherwise?

The teacher moves to another group to check their progress and probe into their understanding of forces. The excerpt below shows the interaction with the third group:

T: Let's find the resultant. Where is the angle on this diagram?

L: Can we not say southeast

T: If the east is given in the diagram then it's fine.

The teacher managed to have learners engaged in activities that helped the development of conceptual understanding. The learners could investigate the concept of resultant forces. The learners through the experiment could make sense of the concept. The teacher managed to occasionally act as a facilitator, though he was still very much at the centre of the lesson. The teacher occasionally attempted to engage learners in discussions and followed learner responses with further probes. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. The tool has four basic categories: instructional factors, discourse factors, assessment factors and curriculum factors.

Table 5.21: Scale statistics for lesson 2 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.4	.49
Assessment	2.0	.00
Classroom discourse	2.4	.49
Curriculum	2.5	.86

The table above shows the inquiry instruction score of 2.33 out of four on all the four categories. The overall score is *developing-inquiry* stage. This lesson was now showing some signs of inquiry in terms of instructional factors and classroom discourse. After the lesson, we had a post-lesson reflection interview and we discussed the lesson objectives, challenges, and remedy. We agreed to improve the classroom discourse and instructional factors, as the following excerpt reveals:

R: I see a change in the lesson presentation. What were your objectives?

T: The learners were supposed to manipulate the apparatus and have an experience of a force. This was ending with calculating the resultant vector.

R: I saw many opportunities that went unutilized, why do you prefer telling the correct answer to asking then probing more?

T: We don’t have enough time, there is much to cover in a short space of time. Would have asked more but I can’t extend the time allocated for science at the timetable. I wish they can allow us extra time in the afternoon for science.

R: I think learners understand more when they participate fully and you need to drive the process. Let them do the talking, you can push them to talk more.

T: Yes I see, it helps. The more they debate on issues the more you can realize their inherent errors. I will try to probe into their answers next time.

The teacher managed to realise the absence of a prolonged engagement between the teacher and the learners. This prolonged engagement is teacher-orchestrated and will allow learners to justify their responses. In the process of justifying their reasoning, the teacher is presented with opportunities to uncover possible learner misconceptions.

5.3.3.3 Lesson 3: Refraction (grade 11)

The teacher has prepared a lesson on refraction. The learners are supposed to see the effect of refraction by performing an experiment in the laboratory. The teacher had introduced the learners to the topic the previous day. He has set up his workstations and the learners are working in groups of fours. The teacher starts by asking the learners about reflection. When asked, the teacher said he wanted them to be clear about reflection before they are introduced to the new concept "refraction". The excerpt below is an example of the interaction between the teacher and the class before the experiment:

T: Yesterday we talked about reflection when we started our topic. What can you tell me about optics, what you learned yesterday?

L: The study of light

T: We said optics is the study of light. Right, what else? We looked at the reflection in particular. What is a reflection?

L1: What did we say is a reflection?

L2: The bouncing of light on surfaces.

T: The bouncing of light from the surface, then we say it is the light surfaces and polished surfaces that reflect light more. What are the laws of reflection?

L: The incident ray and the reflected ray are all in the same plane.

T: Secondly

L: The angle of incidence is always equal to the angle of reflection

When the teacher realizes that the learners remembered well what they did in the previous lesson, he proceeded to the day's work. He informed the learners about the second aspect of light that they were going to explore that day. Each group was supposed to collect the apparatus listed on the whiteboard and follow the given instruction on the instruction sheet provided. In the first experiment the learners were supposed to observe a coin in a beaker full of water and compare it with a coin underneath a beaker full of water. The learners were supposed to come up with their observations and try to look for explanations. In the second experiment, they were supposed to draw two arrows facing the same side on a piece of white paper and observe the arrows as they pass the paper behind a beaker full of water. The learners are to observe the arrows as they bring down slowly the paper until the first arrow is fully covered by the beaker. The excerpt below is a conversation between the teacher and one of the groups.

> T: what is the difference between the coins? The one underneath the beaker.
>
> L: It enlarged.
>
> T: Good, you have made an observation.

The teacher moves to the next group that was already on the second experiment and the following excerpt is the evidence of his interaction with the learners in the group.

> T: If you make them big it will be better. Make them darker.
>
> L: Must it be coloured like fully red.
>
> T: It doesn't matter, make it as dark as possible. What do you observe?
>
> L: It doesn't do anything.
>
> T: Maybe the arrow is too big.
>
> L: If bigger, isn't it the length has increased?
>
> T: Let's make them a bit smaller. Shade them so that they become darker.

In the excerpt above we see the teacher making suggestions, but the learners seem to be following instructions without clear sense of purpose. When all the learners had written down their observations on paper the teacher then asked the learners to come up with the explanations of what happened. The following excerpt is the evidence of the teacher probing the learners for explanations.

> T: Who can give us an explanation for these observations? Is this really what happened? Does it mean the coin wasn't there in the first one? What made it disappear?
>
> L: The way the light is refracted.
>
> T: By what?
>
> L: By the water
>
> T: By the water. That's what you think. Do you know how it is refracted?
>
> L: What I have just said, is it correct? Am I correct?
>
> T: Yeah it has to do with refraction. You have introduced a new word to me. I have to know what you mean by refracted, we haven't yet defined the word. What we are doing is leading to the definition of the word refraction.

The teacher then goes on to explain what happens to light when it moves from one medium to another. The current experiment has more than one medium that light is passing through and in each medium, the light can either bend towards the normal or away from the normal. The teacher went on to explain that water is more optically dense than air, and in turn, glass is more optically dense than water. The light bends towards the normal while it moves from a less dense medium into a more optically dense medium. So when light moves from the air into the water the light will bend towards normal. The teacher then showed the learners how to draw the diagram showing the incidence and refracted rays. The teacher went on to give the definition of refraction at the end. After giving the definition the teacher wrote a question on the whiteboard for the learners to answer as individuals. Interestingly one learner wanted to know if what refraction was going to be part of their coming controlled test.

The teacher managed to have learners actively engaged in investigations, but not consistently and clearly focused. The teacher managed to solicit explanations from learners to assess understanding and then adjusted instruction accordingly. He explicitly encouraged learners to reflect on their learning at an understanding level.
The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that

takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.22: Scale statistics for lesson 3 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.6	0.49
Classroom discourse	2.0	0.00
Assessment	2.8	0.40
Curriculum	2.75	0.43

The table above shows the inquiry instruction score of 2.54 out of four on all the four categories. The overall score is *developing inquiry* stage on the EQUIP levels of inquiry. This lesson was now showing some signs of improvement in terms of instructional factors, curriculum factors, and assessment factors. A post-lesson interview with the teacher revealed that the teacher was now conscious of the need to have quality questions, but had used higher order activities to introduce a concept. The evaluator recommended the use of monochromatic light and let the learners see light being refracted. A commitment was made by the teacher to consider using light in the next experiment on the critical angle.

> R: Your activities, did you manage to reach your goal?
>
> T: I think the good learners may have picked something, but for the majority they may not have benefited.
>
> R: I thought as much, I think they were two complex for a start. I see the coin experiment light is passing through more than two materials, that's difficult to comprehend at start.
>
> T: I will do a similar experiment on the next section. The one on critical angle will be a good one.

The teacher does not find it difficult to integrate activities in his teaching. He finds experiments useful when introducing a concept.

5.3.3.4 Lesson 4: Critical angle (Grade 11)

The teacher greets his learners who are already seated waiting for him. The teacher went straight into the concept of the day. He asked the learners the two conditions for a critical angle. The learners responded very well by giving the two conditions. The teacher then draws a diagram on the whiteboard to show all the learners what the learner who responded to the question meant. The teacher proceeded to explain the concept of internal reflection as an extension of the critical angle. The teacher told the class that they are going to investigate critical angle. As usual, the teacher already has a few instructions on the whiteboard on how to perform the experiment, though not that detailed. The learners started to discuss in their groups on how to go about the investigation. The excerpt below is a discussion between learners in their group before the teacher joins the group:

L1: See there's the second one, I think I have found the second one.

L2: Which one, the second one?

L1: That one on the board with regard to the centre.

L3: What are we going to do?

L2: This is obscure

L3: What do you mean?

The teacher then joins the group and gives the necessary support to allow the learners to proceed with their investigation. The support is in form of probing questions and clarity seeking questions:

T: Do you see the beam, where is it? What does it mean?

L2: Here

T: What does it mean? It's passing through the prism, isn't it? But is it a straight line?

[*Learners say no in a chorus*]

T: What has happened?

L3: It's being reflected, refracted?

T: Which word are you using? How many beams do you see there?

L2: Refracted, I see 4

T: Can you count them

L2: Yes, I see four [*the learner counting*]

The teacher moves on to the other group and makes a comment. The learner felt encouraged and responds very well. The teacher gives guidance on how to manipulate equipment, which seems to be new to the learners. The conversation below shows how the teacher helped with manipulation of equipment during the investigation:

T: Continue shifting until...

L1: That is the critical angle because I'm seeing this 90 degrees

L3: How is that 90 degrees?

T: Where are 90 degrees?

L1: There

T: No

L1: Oh, that 90 degrees - here we go

T: Yes

The teacher then encouraged the learners to compare their set-up and the diagram on the whiteboard. The learners seem to see what to expect and they start to have their group discussions. There is some noise and then one of the learners asked a question on something very important that could have been the stumbling block in understanding the whole set up.

L1: Okay, the other line we don't have it.

T: The normal, yes you don't have it. Remember the definition of a normal, what is it?

L1: The definition of a normal?

L3: [*Reading from a book*] A normal is an imaginary line.

T: Yes, an imaginary line which means you won't see it.

The teacher managed to follow up responses with engaging probes that required learners to justify reasoning. The following excerpt is the evidence.

L1: Waal.

T: It has improved.

L3: There we go.

L2: I’m confused, but there we go

L1: This one is going through

T: It’s not being refracted, how many rays do you see?

L2: I see 2

T: Where is the second one? You said this side there are two?

L2: Now I see two again

T: You said this side there is two, which one has two? Where is the second one?

The communication was often conversational, with more learner questions guiding the discussion.

T: It means some of the rays are refracted and some of the rays are reflected.

L1: Reflection

T: And this is for?

L1: Refraction

L2: So is refraction brighter?

L3: That’s what it looks like

T: look where the beam is, at the corner there. This one is representing the light that is reflected and this one is representing the light that was refracted.

The teacher occasionally lectured, but learners were engaged in investigations that promoted strong conceptual understanding. The teacher managed to follow up responses with engaging probes that required learners to justify reasoning. The communication was often conversational with more learner questions guiding the discussion. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.23: Scale statistics for lesson 4 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	2.8	0.75
Classroom discourse	2.4	0.49
Assessment	3.0	0.00
Curriculum	3.25	0.43

The table above shows an average inquiry instruction score of 2.86 out of four on all the four categories. The overall score is *developing-inquiry* stage. This lesson was now showing some improvement in terms of instructional factors, discourse factors, curriculum factors, and assessment factors. The post-lesson interview discussed the challenges experienced by the teacher as he is enacting inquiry-based teaching. The teacher had reservations with allowing his learners to plan their own investigations. The teacher thought there are selected experiments that he cannot allow the learners to plan and conduct their investigation without his control.

> R: I see you always have instructions ready on the whiteboard, can they not sometimes plan an investigation on their own.
>
> T: It's possible, especially the good ones. The rest of the class may need me to assist them.
>
> R: Have you ever tried it, or its speculation?
>
> T: I know the learners and also there are experiments I do not recommend them to do on their own, especially the chemistry ones.
>
> R: Why chemistry in particular
>
> T: Mostly they are using chemicals and it may not be safe for the learners to use try and error.

The teacher shows concerns about the safety of learner, which is a priority in every investigation.

5.3.3.5 Lesson 5: Heating curve (Grade 10)

The teacher asked the learners to come into the laboratory and perform an experiment on the heating curve. The learners were supposed to work in groups of fours. The teacher was having all the instructions and apparatus listed on the whiteboard. The learners were asked to send a group representative to collect materials and start the experiment immediately. The teacher asked the learners to be calm and cautions since they will be heating up water. The learners collected their materials and started the experiment. The learners are excited to have an experiment; they were even asking if they were going to exhibit Physical Sciences experiments on their oncoming open day for the school. They were giving the reaction of potassium with water and the burning of magnesium as one of the experiments they would want to perform on the open day for that particular year. The other learner was even asking the teacher about the university requirements, this was a good sign the learners were ready for the day's lesson. The teacher sits on his desk for the first ten minutes of the experiment and the learners were busy. He then joins the first group and checks their results and the experiment set up. The excerpt below shows the teacher asking the learners on their decisions made on data collection:

> T: How many recording are you having now?
>
> [*The teacher looks at the paper one of the learners was recording and say*]
>
> T: You are recording after every two minutes. It is too long.

The teacher goes into the storeroom to look for something. When he returned into the laboratory one group of learners was arguing. Some were asking the other learners to put off the flame of the gas burner. The teacher immediately intervenes:

> L: Take it off, turn off the gas
>
> L2: No, leave it
>
> L: What are we supposed to do?
>
> L3: Leave it for a minute, then you put it in and record the temperature
>
> L: Why don't you leave it and record the temperature?
>
> L: Sir, can we have one of these holders to hold the thermometer.
>
> T: Okay you can do that. It's going back to 5 degrees Celsius. [*The teacher stands up and gets closer to the group*.] Now your thermometers are now touching the bottom of the container (beaker). Have you been stirring?

The learners are excited to do the experiment. At the beginning of the experiment when heating ice they struggled with the fact that they were heating and temperature seemed not to increase. The excerpt below shows the learners' discussion as the temperature kept on fluctuating.

> L1: It is 9.5 degrees
>
> L3: How do you go from 9.7 to 9.5 this thing is not measured right?
>
> L: It is 9.5 degrees Celsius
>
> L: Sir, after this what are we going to do?
>
> T: When you finish you write your report. But you still have ice, you must be mixing.

L: Didn't sir say we will do it tomorrow?

T: You can start now and finish it tomorrow.

The teacher moves to another group and the learner's plan had some errors. The learners were removing the beaker from the burner each time they want to take temperature readings. The teacher helped to correct the mistake and allowed them to proceed with the experiment. The excerpt below is the interaction between the teacher and the group members.

T: It is supposed to be continuous, when your time is one minute you record, then after 2 minutes, you record. It is continuous, you don't have to remove the burner and the like. Keep on stirring

L2: What is the temperature 11 degrees?

L: The temperature is now low.

T: Do you know why it is going down. Can you explain what has happened?

L2: It's confusing

T: No, it's not confusing

L2: We keep on moving that thing

L: No

T: When you recorded you were not stirring, now that you are stirring your temperature is now recording uniform temperature for the whole mixture. What you can do you can interchange the two.

The experiment made the learners interested in what they were doing. Learners could relate what was happening to their everyday experiences with the kettle and preparing Noodles. One learner also asked for clarity in terms of how the thermometer works and a misconception was cleared on one learner who thought an alcohol-based thermometer was better than the mercury based thermometer.

L3: Let's say you use this to measure heat and it's at a higher point than this.

T: No, it will not measure; it can only measure up to the maximum temperature there. If it exceeds that it will break.

L2: That's why I was not using this one [*referring to the alcohol-based thermometer*], this one is faster than the mercury-based thermometer.

L3: No, it's the same

T: It's the same.

The teacher draws a table on the whiteboard (time and temperature), saying you are recording your time in minutes, and asking the learners.

L: I know what we are going to do on an opening day. The lithium and potassium, when we drop that thing potassium in water and it goes….

T: We don't have enough of that

L2 We need to make it look interesting.

L3. We can do experiments on the tables.

The teacher asked probing questions to clear misconceptions as they proceeded with the experiment.

L1: The temperature is now 68 degrees Celsius

L2: It's evaporating

T: You said it's evaporating.

L2: Yes

T: Is it boiling?

L2: Yes

T: Are the two the same? Evaporating and boiling?

L3: NO

T: That's why I was asking. Is it evaporating?

L: Yes

T: It means water can evaporate, even if it's not boiling.

The learners are having a long conversation on their own in their group about water and the teacher is seated next to them without disrupting their discussion. Take note, learner number 2 is the one who is manipulating apparatus and taking a reading from the thermometer. He is standing and the other three are seated, recording and observing. The teacher is only coming in when he realises there could be a misconception. The excerpt below shows a lengthy discussion between learners in one group and a few teacher inputs:

L2: I see bubbles. Check there are bubbles.

L4: It's not bubbling

L: I saw bubbles

L3: You get like bubbles but it's not boiling yet

L2: It's not yet, boiling. I am not saying it's boiling

L3: Bubble does not mean its boiling.

T: So what do the bubbles mean?

L2: It's boiling, sir.

L3: It's not boiling properly, keep stirring.

L4: It's starting to boil. Keep stirring

L4: Check the temperature?

L2: Its 80 degrees

L3: Sir, it's not going up any more. I think that's the highest temperature it can reach

T: Stop stirring so that we can see whether it's boiling or not.

L4: Does the Bunsen burner have enough energy?

T: That's the hottest

L3: But there is no other Bunsen burner

T: It should increase temperature since we are heating. It's receiving more energy, more heat energy.

The teacher asked the learners to explore before explanation and both the teacher and learners explained. The instances where the teacher acted as a facilitator also increased, thus frequently acted as a facilitator. A drop was registered on the curriculum factors. The teacher was prescriptive on the ways of collecting data during the experiment. When asked why he did that the teacher mentioned that it was an SBA experiment (formal) and he was not supposed to alter any of the instructions. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.24: Scale statistics for lesson 5 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	3.0	0.80
Classroom discourse	2.4	0.49
Assessment	3.0	0.00
Curriculum	3.25	0.71

The table above shows an average inquiry instruction score of 2.91 out of four on all the four categories. The overall score is *developing inquiry* stage on the EQUIP levels of inquiry. This lesson was now showing some improvement in terms of instructional factors. The post-lesson interview discussed ways to improve classroom discourse. The excerpt below is the evidence.

> R: I find that your learners have good learner to learner interaction during the investigations. How did you manage to establish that?
> T: I think allowing them to carry out the investigations is the catalyst.
> R: I do not see the classroom discussion of the investigation results and their meaning at the end what happens when the learners have results.
> T: They write a practical report which is marked and a mark is allocated to each learner.
> R: After marking what happens?
> T: We do not normally do anything, except record if it's an SBA task.
> R: I think there is a need to look into ways of reporting back to the class so that learners know what was expected and the challenges other learners have with the experiments. The interpretation of results is also an important practice.

The teacher was worried much about the data collection that anything else. At the end of the data collection nothing much was done in class except reporting on the findings.

5.3.3.6 Lesson 6: Reactions of acids and metals (grade 11)

The teacher invites the learners into a class and they find apparatus on their selected tables. The learners are supposed to work in their usual groups and follow the instructions on the whiteboard. The first copy the instructions into their notebooks and discuss the practical as a group as part of the planning process. The teacher expects the learners to know the definition of an acid by now and some of the precautions when working with acids. The teacher is very observant today and he quickly attends to learners. When asked why he was behaving differently that day he raised the concern on learner safety since they were working with chemicals. The excerpt below is his conversation with the first group:

> T: Have you filled your three test tubes. Now you can collect your three test tubes and HCl and go to your workbench. Come and collect the stuff here and these are Iron fillings.
>
> L: How many, sir?
>
> T: Read the Instructions from your book.
>
> [*A learner is pouring an acid in a test-tube and the teacher indicates that they needed just a bit.]*
>
> T: Is this the acid or water that you are spilling here.
>
> L: This is our HCl
>
> L2: This is Sulphuric acid. You guys have HCl?

The learners were concentrating much on the procedural aspect of the practical than the conceptual. The focus was on the doing part of it. A bit of disorder than the other days:

> L: Are we doing the right thing?
>
> T: Find a way of identifying which one is HCL which one is Sulphuric acid. Let's do it, please. Can you write it down?
>
> T: How did you do it? You should have taken your HCL and fill your three once.
>
> L: Yes we have three HCL test-tubes.
>
> T: Can you write HCL here and Sulphuric acid. Remove one that is not there.
>
> L: I can say this one is Sulphuric. Straight down

The teacher moves to the next group. The group is still discussing their plan and they seem to be taking time to come up with something concrete. The teacher joins the group:

T: You guys are too slow. Can you add those things now?

L4: Add Sulphuric acid now?

L2: What is this?

L3: Here are Iron fillings

T: There is a spatula there

L4: Oh, this one it smells like eggs

L1: This one reacted, this one did not and this one reacted.

L2: This one is vinegar and it can't react

T: You must test the gas. [*Like this teacher demonstrate*]

L: Light a splint

T: That one is not burning

[*The Learner lights it up and blows the flame*]

T: Why are you blowing it off?

[*Learner relights and wants to dip it into the test tube*]

T: Don't dip it into a test-tube; just put it at the mouth of the test-tube.

L: Do you see that, do you see that? It switches off when it comes in.

L2: Sir, do we put the iron fillings?

T: You can put some more

L2: You guys, can I have a splint?

L1: I gave you. You don't have to use the whole of it you have to split it.

L2: Sir, it switches off

T: Can you put iron fillings, sorry zinc, in the other ones?

L: This is zinc? [C*onfirms with the teacher*]

The teacher moved to the next group. He quickly invited the members of the previous group to come and observe the other group:

T: Come and check what is happening here. You must test the gas

L: Bring the lighter

T: Can you light your splint? Try to put that right and on the mouth and see what happens

L: Put all on the mouth and there goes a pop sound

T: Yes. Good. You must record that.

After the observation, the learners from the two groups were now discussing together. A learner from the previous group wants to understand why they could not manage to get the same results:

L1: Sir, ours did not work

L2: You should have done it wrong

T: Test each of them

L1: That was acid and zinc, what is the observation?

L2: What's the observation?

T: What do you call that sound?

L1: That's a pop. Pop sound

T: It is called a pop sound

L3: Do the same with HCL/H_2SO_4

L2: Sir, H_2SO_4 and iron fillings do nothing. Iron fillings are not reacting

T: Record what you are seeing

L1: It's reacting, but there is nothing off.

There were moments when learners were having useful discussions about the content and their observations. One of the captured discussions was on which gas was giving a pop sound with a burning splint:

L1: When it’s giving a pop, it’s giving off hydrogen

L2: We didn’t use magnesium. Where is magnesium

T: Oh magnesium ribbons. They got it this group. [*Referring to the next group*]

L3: Look for magnesium ribbon

T: The ribbon. Yah, that one.

L2: Let me do it.

T: You must scratch it. You must remove the grey thing

L2: Is this good enough [*Busy scratching the magnesium ribbon*.]

L3: We put it in the HCL. We can fold it

T: Yah, you can fold it

L: Wooh…

T: Test that gas quickly. You can use a longer one.

L: Tries to lift the Splint

T: Come please let’s test this gas

L: There is a pop sound and the learner says here we go [*In a happy mood*]

L: Sir, it makes that fancy noise

L2: We have got three pops.

The teacher moves to the next group and asks for the results. The learners were confident and responded abruptly. The following was the conversation between the teacher and one of the learners in the group:

T: Any observation?

L1: It was zinc

T: Zinc granules

L1: And we added sulphuric acid and produced a gas. That, when tested with a burning splint, produces a pop sound.

L2: Magnesium also reacted with sulphuric acid to produce a gas that gives a pop sound with a burning splint (or a flame), it produces hydrogen.

The teacher visited the last group for the lesson and helped them perform the last experiment for the day. The learners are excited to see the explosions in the laboratory. This lesson was now showing some improvement in terms of curriculum factors. The teacher challenged learners up to application level. The teacher asked learners to explain, give reasons and justify. A drop was registered on the assessment factors. The teacher assessed prior knowledge but did not modify instruction based on this knowledge. When asked why he did that the teacher mentioned that his time was limited as he was having only 45 minutes to do the experiment. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.25: Scale statistics for lesson 6 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	3.0	0.00
Classroom discourse	2.6	0.49
Assessment	3.0	0.40
Curriculum	3.25	0.83

The table above shows an average inquiry instruction score of 2.96 out of four on all the four categories. The overall score is *developing-inquiry* stage. The post-lesson interview discussed the need to allow learners to have more meaningful discussions and reporting back to the class.

R: You were all over today, why?

T: I don’t like chemistry practical. It has too much risk.

R: What do you mean?

T: The use of acids or chemicals in general puts the learner at risk. I was worried about safety.

R: I still not see learner discussion of results, especially with some of the learners driving the discussion.

T: In this particular lesson learners were lacking knowledge on acids and bases. Much of the time was spent on procedural issues, they were just following instructions as they go.

The teacher tried to help the learners, but it was a futile exercise since the majority of the learners did not have the necessary background knowledge on acids and bases. This lack of required basics may work against the implementation of inquiry in the classroom.

5.3.3.7 Lesson 7: Electricity

The teacher gave a review of the previous lesson. When he gets to parallel resistors, he then tells the learners that he was not going to talk about that as the lesson is going to be on that. The teacher went on to give instructions on what needs to be done. Each group was given two resistors, two cells, three-volt meters, three ammeters, a switch and connecting wires. The learners were to build a circuit on their own that show the parallel arrangement of these two resistors. They were going to work in groups. When asked why he wants them to be working in groups, the teacher indicated that the school does not have enough equipment to work as individuals. The teacher was moving around the groups as the learners were planning on how to build the circuit. He seems to be worried about them doing the wrong thing. The excerpt below is evidence of the teacher interaction with one group.

T: What would you do to check if your arrangement is parallel, not series?

L1: One current should be lower

T: Besides measuring what can you do?

L2: But if you disconnect one bulb the other bulbs will remain working.

T: Just try it, let's see what happens

[*The Learners try it*]

T: Okay, now you can be sure that it is parallel. If it was series you disconnect what happens to the rest.

L: They will all go off

Learners from the next group are busy building the circuit. The teacher joins them and asks probing questions:

T: That ammeter, what current is it measuring?

L: 25

T: That is the value but what current are we measuring

L: Total current

T: Where else do we need to put the ammeter

L: In the two branches

T: Let's connect the other voltmeter. I suggest you call v_1, this one v_2 and this one be v.

The teacher left that group and proceeded to the next group. The learners in the group had finished building the circuit and were busy drawing the circuit diagram and formulating the table of results. The teacher asked the learners to give him the sources of error in the current experiment. The teacher observed the learners as they take readings from the voltmeter and ammeter. The following excerpt is the evidence of the teacher modifying the lesson to address a concept that could be critical for the success of the lesson:

T: Voltmeters and ammeters may not start at zero. There are two ways to do it. You can tune it to zero or. They call it a zero error

L: Compensate either by adding or subtracting the error on the instrument

[*One learner draw the circuit diagram on the whiteboard while others are completing the table of results*]

T: We want to take our reading now so I was asking about the table we can use to record our results

L: We have a table for current and a table for voltage

[*Teacher drafts the table on the chalkboard*]

T: Can you discuss those results

L: The current should add up to 0,45A because resistors in parallel are current dividers.

T: You said the current should let's see whether it's doing that

L: Yes it's doing that 0, 45 A =0, 21 plus 0, 24 A

T: The current must add up to the total current, what about the voltage we got 2,4v, 2,2v and 2,5v what happened?

L: We must take the voltage while the switch is open

T: Do the same for this let's see what you will get

L: It now 2,4v

T: What can you say now?

L: They are all equal

T: Potential difference in a parallel arrangement is equal for all resistors. Any difference can be a result of resistance like he said or wires heating up when measurement is not taken quickly.

The teacher asked learners to explore concept before explanation occurred. Though prompted by the teacher, the learners provided the explanation. The learners were highly engaged at multiple points during the lesson and clearly focused on the task. The teacher successfully engaged learners in open-ended questions and investigations. The communication was often conversational with some learner questions guiding the discussion. The teacher often followed-up response with an engaging probe that required the learner to justify reasoning. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.26: Scale statistics for lesson 7 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	3.6	0.49
Assessment	3.0	0.00
Classroom discourse	2.8	0.40
Curriculum	3.0	0.00

The table above shows the inquiry instruction score of 3.10 out of four on all the four categories. The overall score is *proficient inquiry* stage on the EQUIP levels of inquiry. This lesson was now showing signs of improvement in terms of instructional and discourse factors. The post-lesson interview with the teacher commended him for the good lesson that involved learners' throughout.

R: I liked your approach today

T: The learners have good command of electricity, I have treated the topic well in lower grades.

R: I saw them building the circuits on their own and you had to ask those questions on the set-up. It was really engaging.

T: If I can manage to have them share their ideas as a class and construct knowledge from the evidence. That will be great.

Mr. Moloku finds it easy to include activities in his teaching. He is working on improving his classroom discourse. He needs to build a non-threatening environment where learners are free to express themselves. This takes the commitment of the whole class.

5.3.3.8 Lesson 8: Magnetism (Grade 10)

The teacher has prepared to teach magnetism using two experiments. In the first experiment, the teacher wants the learners to observe the magnetic field lines. The teacher gives the procedure and the learners perform the experiment. The learners managed to draw conclusions from their observations. The second experiment the learners are supposed to design an experiment to prove that a magnet has two different poles. It's a grade ten class and the assumption is they have basic knowledge about magnets from lower grades. The teacher starts the lesson by assessing the learners' prior knowledge of magnets. The teacher did not struggle to engage them in a discussion on magnets. The excerpt below is a discussion the teacher had with the learners as he assessed their knowledge on magnets.

T: What do you understand by that term magnets?

L1: When something has an attraction

L2: When still gets properties of the magnet.

L3: How does a thing magnetize?

T: You can use a magnet.

L1: Iron/nickel

L2: Nickel, cobalt not copper

L3: cobalt

T: These are only two iron and cobalt. They are two only, these ones can result in what is called permanent magnets. Which means we also do have temporary magnets.

The teacher gave the learners instructions on how they were going to carry out the experiment 1. The learners were supposed to observe how the iron filling was arranged in each case and draw the magnetic field lines to represent the observed patterns. After establishing the pattern of magnetic field lines around a magnet, the learners were supposed to draw the diagrams of the magnetic field lines to represent the other arrangements given. The learners are working in pairs and each pair has two bar magnets:

L1: Sir, Can I take a picture of this?

T: Yes, you may. You want to take a picture?

L1: Yes. I want to draw it [*the learner goes on the chalkboard to draw*], I am just going to draw solid lines.

T: Do you know where magnets are ending at the bottom?

T: I'm worried about something your lines...

L2: I know your lines must be ….

T: No, go and draw your own lines by the side.

L1: It's so cool when you have a metal table and sprinkle the iron filings on the table and put the magnets under the table. My dad also has strong magnets, the magnets are too strong - you have to put a piece of cardboard between the magnets to keep them apart.

The teacher invited the class to analyse the two diagrams that were on the chalkboard. The learners gave their input and the teacher then asked them to finish the second part of the experiment where they were supposed to design an experiment. The following excerpt is the conversation between the teacher and one of the groups as it designs its own experiment.

L1: Do we have a compass?

T: You don't need a compass for now. You only need two magnets, we want to say are these poles not the same, Show me by two magnets.

L2: Do we have a piece of string?

T: Yes I have

L2: The learners put a retort stand on the table

T: You have to show me that they are not the same.

[*The learner put the magnets together*]

T: Why can't you use the string, you were doing the right thing, and you two what are you waiting for?

L1: The magnets

[*The learners are tying the magnets in the middle*.]

L2: I will hold the centre of the string.

T: Is that telling you that the poles are not the same.

L2: Yes

T: How?

L1: The opposite poles attract each other.

The lesson provided flexibility for learners to design and carry out their own investigations. The teachers asked the learners to complete the task in the remaining time and submit their papers. In this particular lesson, Mr. Moloku acted frequently as a facilitator. His learners were consistently and effectively active as learners throughout the lesson. The teacher often followed-up responses with an engaging probe that required the learner to justify reasoning. The lesson was further analysed using the inquiry lesson observation tool EQUIP that was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. Each category was then scored according to the following table, on the level of inquiry it represents.

Table 5.27: Scale statistics for lesson 8 EQUIP tool

Category	Scale mean	Scale Standard deviation
Instructional factors	3.6	0.49
Assessment	3.0	0.00
Classroom discourse	2.8	0.40
Curriculum	3.5	0.49

The table above shows the average inquiry instruction score of 3.23 out of four on all the four categories. The overall score is proficient inquiry stage on the EQUIP levels of inquiry. This lesson showed some signs of improvement in terms of curriculum factors. This lesson demonstrates that with greater exposure to investigations in the classroom, learners will gradually be given more opportunity to plan investigations on their own. The post-lesson interview had a review of the lessons from the first lesson to the current lesson. The teacher generally felt the experience was worthwhile. The following excerpt is extracted from their interview:

> R: We have managed to have eight lessons on inquiry, what have changed in your teaching?
>
> T: I have always believed practical work is beneficial when teaching science, but the contextual factors have kept me far from implementing it. This experience has given back my confidence.
>
> R: What can I tell the teacher in the next school who want to learn about inquiry?
>
> T: Good planning and learner support have worked well for me. I think you need to build on skills from lower grades.
>
> R: Can I conclude that the experience was worthwhile?
>
> T: Very encouraging.

Mr. Moluku has increased confidence in inquiry as shown from his descriptions and EQUIP scores.

5.3.3.9 Cumulative summative percentage inquiry scores per lesson

The section presents a summary of the quantitative data generated from EQUIP for the eight classroom observations for Mr. Moluku. The scores for each category are presented from lesson one to lesson eight. The last column shows the percentage inquiry per lesson, which gives a snap shot of the trend from lesson one to eight. The percentage inquiry per lesson was calculated from the total scores of the four indicators expressed as a percentage of the possible score. Thus, the comprehensive total scores was then divided by the possible score (16) and multiplied by 100 to get percentage inquiry per lesson.

Table 5.28: Percentage inquiry in different lessons comprehensive score per category

Lesson number	Instructional factors (4)	Classroom discourse (4)	Assessment (4)	Curriculum (4)	Comprehensive total score (16)	Percentage Inquiry per lesson (100)
1	2.4	1.8	2.4	2.5	9.10	56.88
2	2.4	2.0	2.4	2.5	9.30	58.13
3	2.6	2.0	2.8	2.75	10.15	63.44
4	2.8	2.4	3.0	3.25	11.45	71.56
5	3.0	2.4	3.0	3.25	11.65	72.81
6	3.0	2.6	3.0	3.25	11.85	74.06
7	3.6	3.0	2.8	3.0	12.4	77.50
8	3.6	3.0	2.8	3.5	12.9	80.63

5.3.3.10 Mr. Moloku Summary

The teacher's overall inquiry instructional practice was scored based on the four categories as depicted on each lesson EQUIP tool; instructional factors, discourse factors, assessment factors, and curriculum factors. In the first six lessons the teacher predominantly at the centre of the lesson. The learners were engaged in exploration and meaningful learner to learner interaction. The teacher is teacher-centred but with some active engagement of learners. His lessons were still prescriptive but not in everything and qualified as *developing inquiry*. Mr. Moloku did not struggle with incorporating investigations into his lessons. In lesson six, seven and eight he realized *proficient-inquiry* level. The teacher began to probe the learners' answers and gradually becoming a facilitator in some instances during the lesson. The lessons were largely learner-centred and learners were engaged at all stages of the lesson including giving explanations.

5.4 Interpreting shifts in pedagogical orientation

After the intervention, the POSTT-PS instrument was re-administered to check if there were any changes in the teachers' responses. The results of this post intervention POSTT-PS instrument are displayed in table 5.29 below.

Table 5.29: Descriptive statistics on the shifts in pedagogical orientations of each participant teacher

Name	Pre-intervention and post intervention	Didactic direct (%)	Active direct (%)	Guided Inquiry (%)	Open Inquiry (%)	Mean orientation	Standard deviation
Mr. Charles	Pre-intervention	10	50	40	0	2.3	.64
	Post-intervention	0	30	30	40	3.1	.83
Mr. Moloku	Pre-intervention	0	20	70	10	2.9	.54
	Post-intervention	0	10	50	40	3.3	.64
Mr. Kapok	Pre-intervention	10	30	40	20	2.7	.90
	Post-intervention	10	20	40	30	2.9	.94
Overall	Pre-intervention	6.67	33.33	50	10	2.63	.75
	Post-intervention	3.33	20	40	33.36	3.1	.83

There is a shift in the mean scores for the POSTT-PS of all the three teachers. Mr. Charles's mean score shifted from 2.3 out of four to 3.1 out of four. There was a 35% shift in the mean score. This can be interpreted as the shift in some of his responses toward more inquiry-oriented options. During pre-intervention POSTT-PS the teacher had no responses in open inquiry, but in the post-intervention POSTT-PS, 40% of the responses were open inquiry. The guided inquiry responses in the post-intervention POSTT-PS were 30% of the responses making 70% of his post-intervention POSTT-PS responses being inquiry. A noticeable increase in the inquiry responses from 40% before the intervention to 70% after the intervention. When asked in the follow-up to post-intervention POSTT-PS interview Mr. Charles had more confidence for the learner-centred methods of teaching. He thought learners need more autonomy during practical investigations. When asked why he shifted from a didactic direct option to a guided inquiry option he explained:

> This one is prescriptive. Very prescriptive. There is a lot of teacher involvement in this one. The one I have proposed now gives the learners a chance to propose a method. I think this one is better learner-centred than this one.

The responses to question 2, 4, 6, 7 and 9 shifted. In question 2 there was a shift from a didactic direct response to a guided inquiry response. In question 4 and 7 there was a shift from active direct responses to guided inquiry responses. Finally question 6 and 9 there was a shift from guided inquiry responses to open inquiry responses. When asked the reason he shifted from the active direct responses to open inquiry, he explained:

> There is too much teacher involvement. This one, I took it that its high-order practical. I will then say let them do it on their own. I believe they have learned enough.

Previously he was against the use of open inquiry in the classroom, but after undergoing inquiry-based professional development his options had more open inquiry responses. The table below shows the responses distribution for the pre-intervention POSTT-PS responses versus the post-intervention POSTT-PS responses.

Table 5.30: Results from Mr. Charles' pre-intervention POSTT-PS responses versus the post-intervention POSTT-PS responses

Question	1	2	3	4	5	6	7	8	9	10
Pre	3	1	2	2	3	3	2	2	3	2
Post	3	3	2	4	3	4	4	2	4	2

The table shows a 30% decrease in the non-inquiry responses and a corresponding 30% increase in inquiry responses. This noticeable shift is in agreement with the data analysed from the follow up interview that shows that the teacher has grown confidence in learner-centred methods of teaching. The teacher's recorded the largest shift in the mean score for the POSTT-PS. Mr. Charles shifted from a preferred active direct approach to guided inquiry.

Mr. Moloku's mean score shifted from 2.9 out of four to 3.3 out of four. There was a 14% shift in the mean score. This can be interpreted as the shift in some of his responses toward more inquiry-oriented options. During pre-intervention POSTT-PS the teacher had 10% responses in open inquiry, but in the post-intervention POSTT-PS, 40% of the responses were open inquiry. The guided inquiry responses in the post-intervention POSTT-PS were 50% of the responses, making 90% of his post-intervention POSTT-PS responses being inquiry. There is a noticeable increase in the open inquiry responses - from 10% before the intervention to 40% after the intervention. Five response options shifted and four out of the five were from either active direct or guided inquiry to open inquiry. Only one shifted from open inquiry to guided inquiry. When asked in the follow-up to post-intervention POSTT-PS interview, Mr. Moloku indicated the need for exploration and more learner autonomy during investigations. He thought learners need more autonomy during practical investigations. He explained:

> In C I can see that there is no exploring by the learner which I realise is something that learners should actually do. As they explore they develop some of their scientific skills. C here is learner-centred. If you realize in B the teacher is pouring while the learners are making observations.

C involves the learners in doing the activities themselves, it goes back to exploring, helping them to set up the apparatus, interacting with the apparatus, making observations and recording their observations.

Mr. Moloku has improved in the understanding of inquiry. He had the highest number of inquiry responses in both pre and post- intervention POSTT-PS.

Table 5.31: Results from Mr. Moloku's pre-intervention POSTT-PS responses versus the post-intervention POSTT-PS responses

Question	1	2	3	4	5	6	7	8	9	10
Pre	3	3	2	3	4	3	3	3	3	2
Post	3	3	4	4	3	3	4	3	4	2

The table shows a decrease in active direct and guided inquiry responses and an increase in the open inquiry responses. The teachers' preferred approach remained guided inquiry.

Mr. Kapok's mean score shifted from 2.7 out of four to 2.9 out of four. There was a 7% shift in the mean score and this can be interpreted as the shift in some of his responses toward more inquiry oriented options. During pre-intervention POSTT-PS the teacher had 20% responses in open inquiry, but in the post-intervention POSTT-PS 30% of the responses were open inquiry. The guided inquiry responses in the post-intervention POSTT-PS were 40% of the total responses making 70% of his responses being inquiry.

Table 5.32: Results from Mr Kapok's pre-intervention POSTT-PS responses versus the post-intervention responses

Question	1	2	3	4	5	6	7	8	9	10
Pre	3	2	3	4	3	3	4	1	3	2
Post	3	1	3	4	4	4	3	2	3	2

The table shows an increase in the open inquiry responses. The teacher preferred approach remained guided inquiry with the majority of the responses in both pre and post-POSTT-PS responses.

5.5 Chapter summary

The chapter presented data on the shifts in pedagogical practices of teachers in inquiry-based teaching. This data comes from the second and third phases of the research study and attempts to meet the third research objective; to examine shifts in the pedagogical practices of Physical Sciences teachers in inquiry-based teaching due to an empowerment evaluation approach. The quantitative analysis of lesson observation data for each teacher over a span of eight lessons using the EQUIP observation tool showed a shift from traditional teaching strategies towards an inquiry teaching strategies. The teachers' overall inquiry instructional practice was scored based on the four categories as depicted on each lesson EQUIPS tool; instructional factors, discourse factors, assessment factors, and curriculum factors. The respective teachers mean scores for the EQUIP increased, for example Mr. Charles's EQUIP score was 1.1 out of 4 in lesson one and in lesson eight it was now 3.1 out of 4. This shows an increase in the percentage of inquiry-based teaching in the classroom from 27.5% in lesson one to 78.8% in lesson eight. Similar shifts were realised with the other two teachers: Mr Kapok's EQUIP score was 2.27 out of 4 in lesson one and in lesson eight it was now 3.21 out of 4. This shows an increase in the percentage of inquiry-based teaching in the classroom from 58.3% in lesson one to 80.1% in lesson eight. Mr. Moloku's EQUIP score was 2.28 out of 4 in lesson one and in lesson eight it was now 3.21 out of 4. This shows an increase in the percentage of inquiry-based teaching in the classroom from 56.9% in lesson one to 80.6% in lesson eight.

A quantitative analysis of pre- and post-interventions data collected from POSTT-PS instrument showed a shift in the teacher pedagogical orientation towards inquiry-based teaching orientations. The teachers were found to have more inquiry responses in their post-intervention POSTT-PS compared to inquiry responses in the pre-intervention POSTT-PS. The change can be attributed to the shifts in the teacher's understanding of inquiry and the gaining in confidence with inquiry strategies that may have been a result of reflection on practice and practice teaching realised through the empowerment evaluation programme.

CHAPTER 6: SUMMARY OF FINDINGS, DISCUSSIONS, IMPLICATIONS, LIMITATIONS, AND CONCLUSION

6.1 Introduction

In Chapter four, research findings were presented on the pedagogical orientations, current pedagogical practices, and the challenges experienced by Physical Sciences teachers when implementing inquiry-based teaching. Chapter five presented research findings on the shifts that occurred in Physical Sciences teachers' pedagogical practices while implementing inquiry-based teaching. This chapter (Chapter six) presents a summary of the main findings and discussion of these findings. The discussion of the research findings is presented in three sections according to the three research objectives as follows: (a) the current pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching, (b) the challenges experienced by Physical Sciences teachers in enacting an inquiry-based teaching approach, (c) shifts in the pedagogical practices of Physical Sciences teachers in inquiry-based teaching due to an empowerment evaluation approach. To address the first and second objective, I used the quantitative data from the POSTT-PS instrument and EQUIP tool, and qualitative data from the semi-structured interviews, POSTT-PS instrument, and the follow up to the POSTT-PS interviews. The third research objective was addressed by the analysis of quantitative data from EQUIP (Marshall, Smart & Horton, 2010), a classroom observation tool, and the pre- and post-intervention POSTT-PS data. This summary of the findings provides the answers to the main research question of this study.

6.2 MAIN FINDINGS

6.2.1 The current pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching.

In the first phase of empowerment evaluation, quantitative and qualitative data revealed the following themes:

Theme 1: The teachers prepare learners for the investigations through pre-labs on the experiment.

There is a certain level of competence that is required from a learner to successfully carry out an inquiry-based investigation.

Competence can be defined as a multi-dimensional set of abilities, skills, knowledge, attitudes, and motivational variables that form the basis for mastery of specific situations (Anders et al., 2018). Learners, in many cases, have less than the minimum competence required to navigate their way through an investigation. It is, therefore, the responsibility of the teacher to support the learners towards achieving the minimum level of competence required to navigate through an investigation. Different support strategies include teacher modelling, questioning, facilitating reflection through feedback, facilitating learner collaboration, using laboratory notebooks, and teaching experimental techniques (Llewellyn, 2002; Wellington, 2000; Wu & Hsieh, 2006). In this study teachers utilized teacher modelling, questioning, laboratory notebooks, and teaching experimental techniques to prepare learners for the investigations. Teachers often had background knowledge of what their learners can and cannot do. The teachers are, therefore, able to decide on the kind of support that learners need to carry out an investigation. This support reduces the complexity of an inquiry-based investigation.

Theme 2: The teachers are using structured investigations in inquiry-based teaching.

The teachers are convinced their learners need clear instructions at all the stages of an investigation. They perceived learners as lacking the required competence and experience to navigate through investigations on their own. Teachers explained the frustration that the learners experience when planning an investigation. The planning of an investigation involves conceptualization of the variables. Teachers indicated that many learners have difficulties identifying all the variables, and understanding the relationship between the variables explored in an investigation. They further explained that learner success in designing and performing experiments on their own is highly dependent on the learner's previous experiences with experimental work, which varies from one learner to another. However, teachers indicated that learners may design and carry out an experiment that is similar to what they have done before, especially investigations on casual relationships. All the teachers indicated

that even top achieving learners may find difficulties with designing their own investigation. Other studies have also pointed to difficulties that learners have with designing and conducting investigations (Arnold, Boone, Kremer & Mayer, 2018).
Furthermore, teachers also thought clear instructions and monitoring was for the safety of the learners. Therefore, investigations which take place are largely structured investigations, with teachers providing instructions, while also monitoring, during all stages of the investigation. The findings of the current study are consistent with those of Ramnarain (2010) who found that, in South African schools where science investigations are taking place, investigations are mainly structured investigations with the teacher exercising a great deal of control during all stages of the investigation.

Theme 3: The teachers use inquiry-type examination questions in supporting learners develop data analysis and interpretation skills

Inquiry is a complex and multifaceted activity involving both cognitive and physical activity (Ramnarain, 2014). According to the NRC (1996) inquiry includes a range of activities with a focus on describing objects and events, asking questions, constructing explanations, testing those explanations against current knowledge, and communicating their ideas to others. The teachers make use of inquiry-type examinations questions in class in order to develop the data analysis and interpretation skills of learners.

Although a study by Ramnarain (2014) found some threats to the validity of the inquiry-related questions in written tests and examinations, the teachers have found these useful in the teaching of inquiry process skills. The teachers regarded the use of such paper-and-pencil tasks as a stop-gap measure in view of the lack of physical resources at their schools. However, the latest publication of the National Research Council entitled "A framework for K-12 Science Education" emphasizes the importance of learners experiencing inquiry-based practices, and not merely learning about them (NRC, 2012).

Theme 4: Teachers prioritize the data collection phase in inquiry over other stages

The South African Department of Basic Education through the Curriculum and Assessment Policy Statement (CAPS) re-emphasized the importance of scientific inquiry in the teaching of Physical Sciences. Physical Sciences investigate physical and chemical phenomena through scientific inquiry in order to explain and predict events in the physical environment (Department of Basic Education, 2011). Scientific inquiry entails the practices that scientists engage in as they do their work. The term practices is now used, not only in place of skills, but to emphasize the important coordination of both knowledge and skill. The NGSS identifies eight science practices of which planning and carrying out investigations is one of them. Teachers perceived the majority of their learners as not capable of planning a meaningful investigation in the time available. They thought planning demanded skills that were not common among their learners, especially identifying variables. Identifying variables is a key process skill needed in the construction of a hypothesis and investigation question in fair testing investigations (Ramnarain, 2014). In focusing on data collection, the learners are given a worksheet with the procedure, after which they conduct the experiment, collect data and draw conclusions. Generally, in South Africa, learners have limited autonomy in choosing a question and in planning, but are given more autonomy in collecting data, evaluating data and drawing conclusions (Ramnarain & Hobden, 2015). All the teachers in the study emphasized the need to generate accurate measurements and credible data from an experiment. Teachers indicated that they made sure their learners collected data correctly, and gave the necessary support in this regard. The teacher also asks questions to check if the learners are capable of taking the correct measurements, or first demonstrate how an instrument is used.

6.2.2 The challenges experienced by Physical Sciences teachers in enacting an inquiry-based teaching approach

Theme 1: Inquiry-based teaching in township schools is hampered by lack of resources.

The three teachers in this study believed township schools as inadequately resourced for inquiry-based teaching. The schools lack functional laboratories and laboratory assistants to assist with the gathering and preparation of materials. The teachers do not have time to gather all the materials that are needed for the experiment, and then to test if equipment or chemicals are working. The township schools face a general shortage of resources as they are disadvantaged due to the historical imbalances of a formerly segregated education system that privileged schools for White learners. Ramnarain and Schuster (2004) acknowledge that, despite efforts by the new government to redress the historical imbalances, township schools remain poorly resourced and have scant facilities for practical work in science. In addition, Ramnarain (2015) has highlighted the fact that even though the discriminatory funding policies were reflected in all areas of school funding, the legacy of these policies is (still) most visible in school infrastructure. The teacher's indicated the need for more supplementary teaching and learning materials to support an inquiry-based approach to teaching science. They maintain that the textbooks are inadequate for inquiry learning, and rather support a teacher-directed approach to learning science.

Theme 2: Inquiry-based teaching in township schools faces the challenge of unprepared learners, in term skills.

In order for learners to competently engage in inquiry, they need to have skills such as classifying, communicating, measuring, designing an investigation, drawing and evaluating conclusions, formulating models, hypothesizing, identifying and controlling variables, inferring, observing and comparing, interpreting, predicting, problem-solving and reflective skills (Department of Basic Education, 2011). The absence of many of these skills in a learner means that the teacher must first assist the learner in developing the skills; and then only give them the opportunity to engage in inquiry learning. This lack of skills, therefore, impacts on the successful implementation of inquiry-based teaching. The teachers indicated that they plan lessons for learners to acquire these skills. They highlighted the lack of time for such lessons. The teachers also expressed concern that these skills ought to have been acquired by learners in the GET phase.

Theme 3: Inquiry-based teaching is hampered by the demands of summative assessment.

The teachers identified the demands of summative assessment as one of the factors working against the implementation of inquiry-based learning in South African schools. As in many other countries, South African schools are monitored for leaner performance in standardized tests. The teachers find the pressure too great, especially when teaching the exam class, grade 12. Stakeholders use the results of the grade 12 external examinations to assess the performance of both the teacher and the school. The Gauteng Department of Basic Education (GDE) defines underperforming schools as those that obtained a pass rate of below 60% in the National Senior Certificate examinations; and those whose pass rate dropped by more than 10% in any particular year (Gauteng Department of Education, 2009). Teachers aim to surpass the sixty percent and, if they are above the 60% pass rate, to avoid a more than 10% decrease in results. This is one of the major determinants of the teaching approach used, since teaching and learning in most schools aim for good results in the standardized tests.

Theme 4: Inquiry-based teaching demands a lot of teacher planning, preparation and enactment time.

The teachers indicated that inquiry required more lesson preparation and enactment time. The teachers felt that gathering materials, preparation of the laboratory, and supporting learners required too much time. The teachers even suggested that the Department of Basic Education should provide them with laboratory assistants to assist with the gathering of equipment and preparation of chemicals before the experiment. In an interview, teachers explained that they avoid doing chemistry experiments since it is so labour intensive. The teachers indicated that the time allocated for Physical Sciences on the timetable was not enough to allow for investigations. In an interview on investigations, teachers expressed dissatisfaction with the time allocated for Physical Sciences lessons at their schools. They indicated that a single period of 30 minutes may be too short for an investigation and this probably impacts negatively on inquiry-based teaching. Furthermore, teachers felt that the work to be covered needed more than that allocated on the pacesetter. The pacesetters stipulate the dates and the amount of time to be spent on a particular topic.

6.2.3 Shifts in the pedagogical practices of Physical Sciences teachers in inquiry-based teaching due to an empowerment evaluation approach.

In this section, I discuss the shifts in teacher pedagogical practice that emerged from the data. The shift in each teacher practice is presented according to: (i) pedagogical orientation; (ii) teacher's role in class; (iii) classroom discourse; (iv) teacher support; (v) teacher control; and (vi) understand inquiry-based teaching.

6.2.3.1 Shift in pedagogical orientation

Teacher pedagogical orientation is an important factor in the pedagogical practice of the teacher in the implementation of inquiry-based teaching. All three teachers showed a shift in the mean score for the POSTT-PS instrument, with the highest recorded shift of 35%. The shifts were towards inquiry with teachers selecting more inquiry responses in the post-intervention POSTT-PS than in the pre-intervention POSTT-PS. For example Mr. Charles shifted from a mean score of 2.3 to mean score of 3.1 out of 4; showing that the majority of his responses are aligned to an inquiry orientation. This change can be attributed to participation in professional development that allowed for reflection on teacher practice.

6.2.3.2 Shift in teacher role

The implementation of inquiry-based teaching required a shift in the teacher's role to one of facilitator. During the stock-taking phase, all three teachers exhibited teacher-cantered methods of teaching, in which the teacher asked only closed questions that invoked short answers. Learners were not given an opportunity to explain and discuss concepts. The lessons were dominated mainly by the teacher with only limited learner engagement. The teacher spent much time at the front of the class, either explaining concepts or giving instructions, while learners sat passively in their seats. Over the sequence of lessons, there was a gradual shift in the role of teachers from dispenser of knowledge to facilitator. This shift in role was evidenced by an increase in the EQUIP score for this category. For example, Mr. Moloku's EQUIP score increased from 2.28 to 3.21 (out of 4) in this category. The teachers gave the learners more autonomy over conducting of the experiment and data collection. While the learners were conducting the experiments, the teachers gave support in the form of prompting questions and suggestions, where necessary. The teachers assisted with the analysis of results and the conclusion by giving explanatory examples of how the results could be interpreted. The teachers, with support from the evaluator, managed to shift from a predominantly lecture method (to cover content) to frequently acting as a facilitator.

6.2.3.3 Shift in the classroom discourse

The traditional science curriculum in South Africa placed much emphasis on the transmission of scientific knowledge and viewed the learner as a passive consumer of science knowledge (Ramnarain, 2010). In such classrooms, teacher talk dominates the lesson. This overuse of the teacher-centred approaches can result in learners losing interest in science (Lyons, 2006). Inquiry-based teaching has redefined this traditional teacher-learner relationship. Within inquiry-based teaching, understanding is enriched by engagement with ideas in concert with other people (Anderson, 2007). These kinds of engagements are possible when a teacher creates an environment in which learners' contributions are explicitly taken into account in science lessons (Lehesvuori, Ramnarain & Viiri, 2017). This suggests that classroom interactions can be nurtured to a level where meaningful learning can result from classroom discussions. In all this, the teacher is instrumental in initiating, extending and maintaining an environment that promotes open discussions.

Analysis of data coded as changes in discourse factors, revealed that teachers managed to shift their discourse factors significantly during the course of the empowerment evaluation program. This was inferred from the increased EQUIP score for the classroom discourse. For example, Mr. Charles's classroom discourse score shifted from 1.0 to 3.2 (out of 4). In terms of percentages, classroom discourse scores of 25% in lesson one shifted to 80% by lesson eight.

At the beginning, communication was directed and controlled by the teacher and followed a didactic pattern; but at the end of the empowerment evaluation programme, communication was conversational. At the beginning teachers asked closed questions that rarely challenged learners' understanding; and learner's answers were rarely followed-up with further probing. But we saw an improvement in the classroom interactions to exemplary inquiry by the end of the EQUIP inquiry protocol. There was a significant shift to questions that challenged learners, at various levels, to support learning. Furthermore, the complexity of the questions increased; from merely seeking information, to requiring learners to explain and justify themselves. In addition, the learners were encouraged to critique other learner's responses. The questioning ecology shifted from closed questions, which did not lead to discussion, to open-ended questions. Despite the significant changes in the quality of teachers' questions, teachers struggled to establish and sustain discussion during lessons.

With support from the critical friend, the teacher used meaningful discussions, initiated by the learners, to clear misconceptions that had surfaced during learner interactions. At the end of the program, the teacher consistently and effectively facilitated classroom dialogue.

6.2.3.4 Shift in teacher support

As learners' progress through an investigation, different forms of teacher support are required. The nature of this support must leave the responsibility and ownership of the task to the learners; otherwise it becomes tantamount to interference. The most common kind of support offered by teachers to their learners during investigations is the asking questions and giving of suggestions: "Questioning can play a pivotal role in helping learners obtain a sense of structure and direction in an investigation" (Ramnarain & Hobden, 2015:113). There are many reasons why teachers ask questions in class, and inquiry-based teaching demands good questioning skills. In inquiry-based teaching, teachers support comes in different forms and is expected at all stages of the inquiry process. Studies in South Africa have shown that the asking of probing questions and the making of suggestions are the major support strategies used by teachers during investigations (Ramnarain, 2011). In inquiry-based teaching, the ability to use questions to facilitate learning is an important skill needed for the success of the lesson. In the present study, a noticeable overall shift in the reasons and motives for supporting the learners during investigations occurred.

During the initial lessons, it was clear that the teacher only wanted the learners to complete the task within the time of the lesson. This can be viewed as teacher control instead of support since the objective was mainly to pace the learners in order that they complete important stages of the investigation within a specified time. As a result of the reflective interviews, the teachers' focus changed from mere helping learners to finish a task within the allocated time, to helping the learners to navigate through an investigation. As mentioned, the reflective interviews took place after each lesson. In these interviews, the teacher, together with the evaluator, identified curriculum design gaps in the methodology used with an aim to improve successive lessons.

6.2.3.5 Shift in teacher control

The enactment of inquiry-based teaching requires the letting go of authority (Crawford, 2000). The teacher needs to be a facilitator, which requires letting go of teacher control. The enactment of inquiry-based teaching requires a balance between teacher control and learner autonomy. The teacher needs to let go some of the control and allow learner independence. During stock taking, teachers expressed their personal beliefs that a teacher should be in control of their classroom. During the first lessons observed, the teachers had control over all the activities. The teachers shifted their approach in the subsequent lessons where they incorporated experimental work and learners were given an opportunity to manipulate materials, collect data, analyse and draw conclusions. The teacher still had control over what transpired in the classroom, but they relinquished some authority as learners were given the opportunity to conduct experiments and draw conclusions. Over time the learners were given greater independence to perform the experiment and discuss their findings. Mr. Charles and Mr. Moloku managed to enact a lesson where learners were also given authority over the planning and implementation of the experiment.

6.2.3.6 Shift in teacher understanding of inquiry-based teaching

There was a notable shift in the way teachers understood inquiry-based teaching. This finding is in agreement with the findings of Capps and Crawford (2013) which showed a shift from less informed to more informed views of inquiry after an inquiry-based professional development experience. At the beginning of the study, teachers had a limited understanding of inquiry-based teaching. They conflated learner-centred methods of teaching with inquiry-based teaching, and were tempted to think that anything that is not a 'telling method' is inquiry. They associated inquiry with asking questions, searching around for information and verification type of experimental work. When the teachers were asked to describe a lesson in which they used inquiry-based teaching, they described an investigation where learners were involved in hands-on activities and constructing explanations from evidence gathered through observations. They acknowledged the importance of guidance when learners are engaged in investigations, but at the same time thought teacher support during investigations was a form of interference especially, in open inquiry.

The teachers thought that, in an open inquiry, the teacher must not help with the investigation. They had the notion that the teacher "folds their hands" and waits for the learner to do everything. One teacher argued that learners do not have the required competences to perform open-inquiry investigations. After the intervention, the teachers had an improved understanding of inquiry-based teaching. The teachers now highlighted important practices in their discussions of inquiry teaching methods. The teachers now perceive inquiry as involving learners doing the activities (exploring), interacting with the apparatus, making observations and recording their observations while the teacher gave some guidance to the learners. The findings of the current study are consistent with those of Rushton, Lotter and Singer (2011) who found that the teachers developed more complete conceptions of classroom inquiry after a year-long inquiry professional development programme.

6.3 DISCUSSION

The purpose of this study was to capture, portray and develop the pedagogical practice of Physical Sciences teachers in inquiry-based teaching using an empowerment evaluation approach. This section discusses the main findings of the study and their significance to science education in general. A comparison is made between the current research and previous studies in science education and teacher education in South Africa. The main findings will be explained with respect to the conceptual and theoretical framework.

6.3.1 POSTT-PS quantitative and semi-structured interviews qualitative data

Successful enactment of inquiry science teaching means, among others, that teachers know how to prepare for an inquiry lesson, guide students to engage with the content, explore scientific phenomenon, and interpret results (Schwarz, 2009). The first research objective concerned establishing the current pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching. The first important results indicate that teachers in township schools had an active direct science teaching orientation, which involved presenting science directly, accompanied by teacher-controlled experimental work. The findings of the current study are consistent with those of Ramnarain and Schuster (2014) who found that teachers at township schools have a strong active direct teaching orientation, involving direct exposition of science associated with confirmatory practical work. The three teachers' mean scores range from 2.3 to 2.9; with an overall mean score around 2, which is interpreted as active direct orientation. One could, argue that a practicing teachers might be inclined to one approach, but studies have revealed that beliefs about science teaching and learning interact with knowledge of instructional strategies (Demirdogen, 2016) and teachers may hold contrasting epistemological beliefs (Bryan, 2012). In addition, some teachers have preference for different teaching strategy in relation to their different goals and targets (Gado, 2005).

The results also indicate that teachers in township schools were using structured investigations for inquiry-based teaching. This finding is in agreement with a study by Trumbull, Scarano and Bonney (2006) which revealed that scientific inquiry continues to be presented in teacher scripted labs where learners follow directions to confirm textbook answers. In agreement, Ramnarain (2010) conducted a study in South Africa which found that investigations taking place in township schools are largely structured investigations where the teacher exercises a great deal of control over the stages of the investigation. Studies throughout the world have revealed similar findings (Abd-El-Khalick, et al., 2004), that investigation remain largely teacher controlled despite curriculum imperatives for learners to have more autonomy in doing investigations. The teachers in the current study held conflicting beliefs about teaching Physical Sciences. The teachers strongly believed that inquiry-based teaching was beneficial for their learners, especially when it offered opportunities to design methods and construct explanations based on the evidence from hands-on activities. However, they also strongly felt that their learners were not ready to learn that way. This may explain why teachers resort to structured investigations “punctuated by teacher control.”

Another important finding was that teachers prioritize the data-collection phase in inquiry over other stages during their inquiry-based teaching. The teachers considered the planning of investigations to be too difficult for their learners, and that the learners were not competent enough to efficiently plan meaningful investigations. The teachers indicated that the learners struggled with identifying the independent, dependent and control variable in an experiment.

The second research objective focused on determining the challenges experienced by Physical Sciences teachers in enacting an inquiry-based teaching approach. Results reveal that inquiry-based teaching in township schools is hampered by lack of resources, unprepared learners, insufficient time and the pressure imposed by looming summative assessments. The present findings seem to be consistent with other research (Newman et al., 2004; Ramnarain & Schuster, 2014; Roehrig & Luft, 2004) which identified contextual factors such as: availability of resources; teacher competence and confidence; time constraints; and student ability, as influencing the methods adopted by teachers. The general poor performance, of students at township schools, in high-stakes summative examinations has encouraged teachers to resort to direct approaches to teaching science. As mentioned in the literature review, teacher-centred instructional approaches that focus on basic skill development are often reinforced at lower performing schools (Perrault, 2000). These schools tend to resort to these approaches as they can be effective ways of raising the school’s overall performance or learner test scores. Teachers at township schools perceive a didactic approach to be effective in preparing learners for tests (Ramnarain, 2014). The teachers indicated that they are measured by the percentage work coverage, which is calculated from the amount of content the teacher has covered in comparison with the expected content coverage according to the pacesetter. In addition, teachers are also measured by the performance of their learners in standardized tests, through the summative assessment scores. This encourages the teacher to tailor their teaching according to the expected questions in the standardized tests, at the same time allowing better coverage of work in the pacesetters. Furthermore, inquiry-based teaching is perceived as time-consuming. All this together encourages a method of teaching that is believed to cover more work in less time.

6.3.2 Classroom observation data

This section illustrates the pedagogical practice of each of the three teachers; and the overall pedagogical shifts achieved by the empowerment evaluation approach used in this study. I used the Electronic Quality of Protocol (EQUIP) before and during empowerment evaluation professional development, and teachers' quality of inquiry-based teaching significantly increased across all the four EQUIP factors. All participant EQUIP scores increased by a minimum of 22% and a maximum of 50%. This was interpreted as an increase in the use of inquiry-based strategies in the classroom, with the participant who started with an active direct orientation showing the biggest increase. With collegial support from the evaluator the teachers managed to shift from pre-inquiry to proficient inquiry. The findings agree with the findings of Singer, Lotter, Feller and Gates (2011) that after professional development teachers were able to successfully transfer the enactment of inquiry-based practices into their classrooms.

The results suggest that the empowerment evaluation professional development model is effective in increasing teachers' ability to shift practice from traditional to inquiry-based teaching. Empowerment evaluation can provide important scaffolding for teachers implementing new instructional strategies. The study provides evidence that supports the need to provide context-specific professional development that includes practice teaching and reflection opportunities. The practice teaching, followed by immediate feedback and teacher reflection on practice, allowed the participants to develop confidence in inquiry teaching. One of the most fulfilling experiences, as indicated by the participants, was to witness their learners learning through inquiry. The reflection process was facilitated by the critical friend and was an ongoing process in an atmosphere of trust.

All the teachers managed to incorporate inquiry into their teaching with all of them achieving the level of *proficient-inquiry.* As expected their pathway to *proficient-inquiry,* as well as the quality of the shifts, varied among the teachers; since teacher practice is influenced by contextual factors and teacher beliefs, which are rarely the same. The most prevalent form of inquiry was having learners conduct the investigation, collect data and draw conclusions. The teachers provided the question and the procedure in form of written or verbal instructions. Only two teachers managed to achieve an investigation for which the learners where required to design an experiment. Although there was an attempt to involve learners in the planning of the investigation, the teachers did not go through all the inquiry stages.

6.4 IMPLICATIONS

The successful implementation of the reformed efforts by the Department of Basic Education is highly depended on teacher professional development. Teachers are critical to the success of every reform effort; and successful implementation of inquiry-based teaching in South Africa is an imperative. This study investigated an empowerment evaluation approach to enhance the pedagogical practice of teachers in inquiry-based teaching. This section presents the implications of the study.

6.4.1 Teacher Development

The success of reform efforts in science education demand effective teacher professional development. This study has important implications for teacher education, both pre-service and in-service. Firstly, there is evidence that in-service teachers benefit from long-term professional development programs that are coupled with opportunities for practice teaching and reflection on practice.

Inquiry-based professional development programs should assist teachers in enacting inquiry in classrooms, and avoid replicating the more common ‘one-size-fit-all’ short programs prevalent in South Africa. This study examined three high school Physical Sciences teachers’ ability to shift their teaching practice towards inquiry teaching while receiving collegial support from a critical friend. The study suggests that some in-service teachers are capable of inquiry-based teaching when they undergo a professional development program, despite the challenges. The majority of Physical Sciences teachers, who are attempting to implement inquiry-based teaching in the many township schools, may be facing the same challenges and may need the same professional support to successfully implement inquiry-based teaching. The transition from traditional methods of teaching science to inquiry-based teaching is not easy.

The teacher is at the centre of any innovation in education, and this study has established that teachers are faced with many challenges in their attempt to carry out investigations. Teachers have bemoaned the lack of support from the Department of Basic Education by expressing dissatisfaction with the level of support they were given (Kriel & Basson, 2008). The current cascade models of in-service training (consisting of one-shot workshops that assume 'one size fit all') are common in South Africa (Ramnarain & Ramaila, 2012). The professional development of in-service teachers in inquiry-based teaching requires a different kind of development.
They should be context specific and take into consideration the needs of the individuals. It is, therefore, of paramount importance that professional development programs take contextual factors into consideration, and allow for immediate classroom practice and refection on practice. Empowerment evaluation is one such development program that uses consistent and continuous evaluation at every stage of development to initiate self-reflection, which in turn gives rise to self-determination. When adopted as a method for professional development, schools can make use of their experienced educators to facilitate professional development of other teachers in inquiry-based teaching. Teacher professional development must be an ongoing practice within the school, where novice teacher receive induction programs that inculcate inquiry-based teaching strategies. The experienced teachers must be trained in inquiry-based teaching strategies to enable them to become agents of change through professional development programs that model empowerment evaluation.

6.4.2 Inquiry-based teaching

Inquiry-based teaching in South Africa is a reform initiative by the Department of Basic Education. One of the mandates of the Department of Basic Education is to redress the injustices of the past, which created a large gap between the ‘outputs’ of schools in different communities. The accessibility and quality of education were racially determined, to the detriment of the black communities, which, for long, have been deprived of access to good quality education. Present South Africa still has the ‘footprints’ of the apartheid era, with schools, previously designated for certain races, still populated by those races (Chisholm & Sujee, 2006). A study by Ramnarain and Schuster (2014) found remarkable differences between the orientations of teachers at township schools and teachers at more privileged suburban schools, with teachers at township schools holding an ‘active direct’ orientation, while teachers at suburban schools exhibited a ‘guided inquiry’ orientation. The current study has found the same patterns, which suggests the need for drastic efforts to improve professional development programs in South Africa. It can be inferred that there are still variations in the way science is presented to learners in the different schools in South Africa. The differences in the teacher orientations to science teaching may mean different contextual factors, with some schools having factors that support inquiry-based teaching and some having factors that inhibit inquiry-based teaching.

This implies that curriculum implementation is still highly context specific, and that professional development programs should acknowledge these different contexts.

6.4.3 External assessment

The current external assessment methods are placing pressure on the quantity and quality of practical work. The assessment has much focus on the cognitive process skills, a factor that does not help with the promotion of inquiry-based teaching. Teachers are now focusing their attention on the drilling the skills required by the practical investigative question that is examined.

6.5 Recommendations

South Africa needs to be at par with other countries in the world in terms of scientific literacy. This important vision is achieved through the training and development of teachers who are capable of actively organizing learner inquiry and active learning. The importance of teacher professional development cannot be overemphasised as a way of building confidence in new methods of teaching. Inquiry-based teaching is one such innovation that teachers need to be equipped to implement successfully in their classrooms. The professional development of the teachers should consider the different contexts in which teachers work and must have opportunities for immediate practice teaching on concepts learnt. Experienced teachers may be useful in training the novice teachers on inquiry-based teaching using empowerment evaluation.

The government must prioritise the township schools in the procurement of support materials for inquiry-based teaching. In order to lessen the burden on the science teachers the government needs to employ laboratory technicians that help with gathering and preparation of the required materials for investigations. The external examinations must include practical work as a way encouraging inquiry-based teaching.

Future research could investigate the viability and impact of an empowerment evaluation approach within communities of practice at schools and in school clusters. In this regard, subject advisors can be instrumental in initiating communities of practice so that empowerment evaluation pairs may be established whereby teachers can be supported in taking stock of their practice, setting goals and documenting progress. Within teaching communities, ‘keystone species’ who act as evaluators to colleagues with professional development needs should be identified. The management of schools needs to support teachers within schools and across schools so that communities of practice can be established. Where possible, formal arrangements need to be made with ‘keystone species’ at other schools so that these teachers may act as critical friends to other teachers who are in need of professional development.

6.6 Limitations

The current study being a case study of three secondary school teachers, it is difficult to make generalizable claims based on its findings. The study was not designed to investigate a one-size fit all solution to all challenges facing teachers. It is evident in South Africa that schools differ vastly in terms of both human and physical resources (Rogan and Grayson, 2003) and these factors greatly influence the extent to which teachers have embraced an inquiry-based pedagogy. The study therefore be conducted on a larger scale and at different schools types that are reflective of the South African school landscape.

Time and budget also limited the number of school visits. According to Fetterman (1999), empowerment-evaluation is labour-intensive and requires an investment in time. If the engagement with the teachers was more regular it is possible that the shifts towards an inquiry-based pedagogy could have been more pronounced.

6.6 Conclusion

The study has demonstrated how an empowerment evaluation approach influence and shift the practice of Physical Sciences teachers towards an inquiry-based pedagogy. Empowerment evaluation gives the participants opportunities to learn new classroom practice in the contexts within which those practices were used which could be different from the traditional professional development programmes. The study provides evidence to support the need to provide context-specific professional development which includes practice teaching and reflection opportunities. The practice teaching followed by immediate feedback and teacher reflection of practice allowed the participant to gain confidence in inquiry instructional skills and a chance to witness learners learning through inquiry.

In addition, The study revealed shifts in each of the following teacher practices (i) pedagogical orientation (iii) teacher's role in class, (iii) classroom discourse, (iv) teacher support, (v) teacher control, (vi) understand inquiry-based teaching.

Furthermore the study revealed that Inquiry-based teaching in township schools is hampered by lack of resources, unprepared learners, insufficient time and pressure of summative assessments. These perennial challenges need to be addressed through prioritizing resource allocation in order to redress the inequalities of the past.

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APPENDICES

Appendix A: University ethics clearance

UNIVERSITY OF JOHANNESBURG

ETHICS CLEARANCE

Dear CT Rudzirai

Ethical Clearance Number: 2014-006

Re: Enhancing the pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching through empowerment evaluation

Ethical clearance for this study is granted subject to the following conditions:

- If there are major revisions to the research proposal based on recommendations from the Faculty Higher Degrees Committee, a new application for ethical clearance must be submitted.
- If the research question changes significantly so as to alter the nature of the study, it remains the duty of the student to submit a new application.
- It remains the student's responsibility to ensure that all ethical forms and documents related to the research are kept in a safe and secure facility and are available on demand.
- Please quote the reference number above in all future communications and documents.

The Faculty of Education Research Ethics Committee has decided to

☒ Grant ethical clearance for the proposed research.
☐ Provisionally grant ethical clearance for the proposed research
☐ Recommend revision and resubmission of the ethical clearance documents

Sincerely,

Prof Geoffrey Lautenbach
Chair: FACULTY OF EDUCATION RESEARCH ETHICS COMMITTEE
12 February 2014

Appendix B: GDE approval letter

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no: D2014 / 387

GDE RESEARCH APPROVAL LETTER

Date:	19 March 2014
Validity of Research Approval:	19 March to 3 October 2014
Name of Researcher:	Rudzirai C.T.
Address of Researcher:	No 602; C.J.S. Centre
	Tom Jones and Bedford Streets
	Benoni
	1501
Telephone Number:	071 959 1297
Fax Number:	011 426 2383
Email address:	clivetrust@gmail.com
Research Topic:	Enhancing the pedagogical practice of South African Physical Sciences Teachers in inquiry-based teaching thorough empowerment evaluation
Number and type of schools:	FIVE Secondary Schools
District/s/HO	Gauteng East

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

2014/03/20

The following conditions apply to GDE research. The researcher may proceed with the

1

Making education a societal priority

Office of the Director: Knowledge Management and Research
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

1. *The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
4. *A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

[signature]

Dr David Makhado
Director: Education Research and Knowledge Management

DATE: 2014/03/20

2

Making education a societal priority

Office of the Director: Knowledge Management and Research
9th Floor, 111 Commissioner Street, Johannesburg, 2001
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Appendix C: Request for principal permission and consent form

C.J.S centre
Tom Jones & Bedford
Benoni
28 March 2014

The Principal
---------------Secondary School

REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT YOUR SCHOOL

My name is Clive T. Rudzirai and I am a PhD learner at University of Johannesburg (UJ). I am conducting research on Science education under the supervision of Professor Umesh D. Ramnarain (UJ, South Africa) and Professor Josef De Beer (UJ, South Africa). The Provincial Department of Education and the district Director have given approval to approach schools for my research. Copies of the approval letters are attached.

I am hereby seeking your consent to conduct the study at your school. I was working with one Physical science teacher from each school. The research does not involve learners and was conducted after school hours.

Aims of the Research

The research aims to:

- establish the current pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching
- determine the challenges experienced by Physical Sciences teachers in enacting an inquiry-based teaching approach
- examine shifts in the pedagogical practices of Physical Sciences teachers in inquiry-based teaching due to an empowerment evaluation approach

Significance of the Research Project

The study will investigate the feasibility of an empowerment evaluation approach as a viable and sustained form of professional development for teachers in implementing an inquiry-based pedagogy. It is envisaged that the findings of this study will provide guidelines for the professional development of teachers in inquiry-based teaching. These guidelines may also inform policy on the professional development of pre-service and in-service Physical Sciences teachers.

Benefit of the Research to the schools

Dissemination of results to schools, Gauteng Department of Education, and the broader public.

Research Plan and Method

Physical Sciences teachers at your school are given a questionnaire on their practice and one teacher is selected for the study. A total of ten thirty-minute interviews was conducted with the teacher after school and five classroom observation as he is teaching. Analysis of the teacher's planning will also be done and reasons for his actions/decisions sought. The research was the only person interacting with the teacher until the end of the study. All information collected was treated in strictest confidence, and neither the school nor individual teachers was identifiable in any report written. Participant may withdraw from the study at any time without penalty. The role of the school is voluntary and the principal may decide to withdraw the school participation any time without penalty. If the teacher-participant requires support as a result of their participation in the study steps can be taken to accommodate this.

School involvement

Once I receive your consent, I will approach the teachers and arrange on the best time for data collection.

Further information

If you have any further information you need to be conveyed to you feel free to contact me on 071 969 1297 or email: clivetrust@gmail.com.

Thank you for taking time to read this information.

Researcher

Clive T. Rudzirai

Enhancing the pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching through empowerment evaluation.

School Principal Consent Form

I give consent for you to approach teachers in the science department to participate in the research study.

I have read the project information statement explaining the purpose of the research project and understand that:

- The role of the school is voluntary
- I may decide to withdraw the school's participation at any time without penalty
- Physical science teachers was invited to participate and their consent was sought before the study commences.
- Only the teachers selected and willing will participate in the study
- All information was treated in strictest confidence
- The teacher's names will not be used and individual teachers will not be identifiable in any written report about the study.
- The school will not be identifiable in any written report about the study.
- The participant will withdraw from the study at any time without penalty.
- A report for the findings was made available to the school
- I may seek further information about the study from Clive T. Rudzirai **contact number 0719691297** or **email:** clivetrust@gmail.com**.**

____

____

Principal   Signature

____

Date

Appendix D: Teacher's consent form

Enhancing the pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching through empowerment evaluation

Teacher Consent Form

I give consent to participate in the research study.

I have read the project information statement explaining the purpose of the research project and understand that:

- My role is voluntary
- I may decide to withdraw my participation at any time without penalty
- All information will be treated in strictest confidence
- My name and surname will not be used and I will not be identifiable in the written report about the study.
- The school will not be identifiable in any written report about the study.
- A report for the findings will made available to the GDE
- I may seek further information about the study from Clive T. Rudzirai **contact number 0719691297** or **email:** clivetrust@gmail.com.

____________________________ __________________

Teacher name and Signature

____

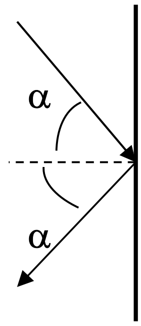
Date

Appendix E: POSTT-PS instrument

The following items present teaching and learning scenarios. Ring the letter of the response that you consider most similar to how you would teach the lesson. Please take note that there are no responses that are incorrect. Expand on your choice in the block, and also why you did not choose each of the other options.

ITEM 1: Light reflection

Ms. Baker is teaching her 8th grade learners the law of reflection: when a ray of light strikes a mirrored surface, it leaves at the same angle as when it arrived. Ms. Baker has to decide how she will teach the lesson.



Thinking about your own teaching, of the following, which is most similar to how you would teach the lesson?

A. I would write the law of reflection on the board and illustrate with a diagram. Next I'd show them a real example, using a light ray source, mirror, and protractor. Then we would discuss any questions the learners might have.

B. I would first pose a question about reflection for the learners to explore. The learners could investigate using light ray sources, mirrors, and protractors, and then discuss their findings. I would close the lesson by giving them a summary of the law of reflection.

C. I would ask learners to find out what they can about light behaviour around mirrors by exploring on their own with an assortment of available items, including light ray sources, mirrors, and protractors. Then the learners would report back on what they did and what they found out.

D. I would write the law of reflection on the board and illustrate with a diagram. Then I'd have the learners verify the law using light ray sources, mirrors, and protractors. We would then discuss their findings.

ITEM 2: Finding the density of a mystery substance

Mr. Cobb's 8th grade learners have learned the concept of density, through examples of solid objects whose mass and volume could be measured. Mr. Cobb next sets learners an 'application' experiment where they have to *apply* their knowledge of density. He provides a 'mystery element' in granular form as shown. The learners' challenge is to devise a method of finding the volume of this substance, take the necessary data, calculate density, and hence suggest what the mystery element might be. (They will have to use a water displacement method to measure volume since there are air spaces between granules).

Thinking about how you might teach, which one of the following approaches would you suggest that Mr. Cobb use for this lab activity?

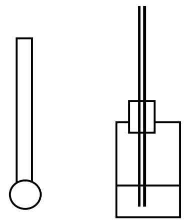
A. Provide learners with lab worksheets giving the experimental method and procedural steps. Learners follow this and enter their experimental data in blank tables on the worksheet. They then calculate density and give their result and conclusion.

B. Provide learners with an instruction sheet which outlines the experimental method. Learners follow this and record data in a way of their choosing in their lab notebooks. They then calculate density and give their result and conclusion.

C. Do not provide method or instructions but have learners first propose and develop a method they intend to use. Before going ahead they discuss this with Mr. Cobb, get feedback, revise if necessary, and then go ahead with their experiment, calculations and result.

D. Leave learners to their own devices as much as possible; they should figure out a method on their own and decide what measurements to take and how. They then do their experiment their own way, and write up their method, result and conclusion.

ITEM 3: Thermometers and how they work



Mr. Ndlovu is developing a science lesson for his 4th grade learners, in which he would like them to acquire an understanding of thermometers and how they work. He has real thermometers available. He also has materials that learners could use to assemble their own basic thermometers (small bottle as bulb, cork with hole, straws and coloured water). Mr. Ndlovu considers four different ideas about how to structure and teach the lesson.

Thinking about how you would teach, which one of the following is most similar to the approach you would take?

A. Start by telling learners that today they will make a mystery device, see how it behaves and then try to conclude what it might be used for. Then show the learners how to put their materials together, and have them explore what happens to the water column in the straw when they put the bulb in cold and hot water. Ask them to suggest what they have 'invented' and what it can be used for. Finally wrap up with a discussion of thermometers and how they work.

B. Write the lesson title 'Thermometers' on the board and draw a thermometer diagram. Then explain how a thermometer works and answer learner questions. Conclude by placing a real thermometer in cold and hot water and showing learners how the thermometer reading changes.

C. Ask the class what they know about thermometers. List learner responses on the board, and then working from some of their ideas, draw a thermometer and explain how it works. Then have learners use thermometers at their tables, measuring the temperatures of cold and hot water.

D. Start by telling the class that today they will discover something for themselves. Each group will have a bottle, cork, straw and coloured water, plus containers of hot and cold water. Show them how to assemble the materials but give no further guidance. They can explore as they wish and come up with ideas, which they can then report to the class.

ITEM 4: Acid-base Indicator

Mr. Peters is planning chemistry lessons for his 7th graders. Online, he found that red cabbage juice can be used as as “indicattor” to test for the pH of common household chemicals, such as lemon juice, ammonia, and bleach.At 7th grade, the only concept that he wants learners to understand is that there are some chemicals that change color when mixed with acids or bases and the color can also indicte the strength of the acid or base. Mr. Peters is not sure how he might use the cabbage juice in an activity or if he should at all.

Thinking about how you would teach, of the following, which is most similar to how you would advise Mr. Peters? Assume any activities are done safely.

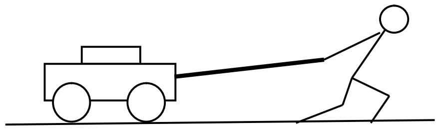
A. Mr. Peters should first explain that acid-base indicators are chemicals that change colour when in acids or bases. He should have a lab activity ready for the learners where they can then verify the indicator effect by observing what happens when they add red cabbage juice to lemon juice, water, ammonia, and detergent.

B. Mr. Peters should ask learners to watch closely as he pours red cabbage juice into a vial of water, and then into an unlabeled vial of lemon juice. He should then ask them if they have any ideas about what happened. Then he should have them try pouring red cabbage juice into labeled vials of lemon juice, ammonia, and bleach. After discussing their observations, Mr. Peters should explain the concept of acid-base indicators.

C. Mr. Peters should give his learners a set of labeled viails with red cabbage juice, lemon juice, ammonia, and laundry detergent, along with a set of empty vials. He should have his learners try mixing pairs of chemicals in the empty vials and recording their observations. He should conclude the lesson by having learners go online to find explanations for what they observed.

D. Mr. Peters should first explain that acid-base indicators are chemicals that change colour when in acids or bases. Using red cabbage juice as an example, he should then demonstrate how the juice turns different colours in lemon juice, water, ammonia, and laundry detergent.

ITEM 5: Lesson on force and motion



Ms. Brandt is preparing a lesson to introduce her 5th grade learners to the relationship between force and motion, namely that a net force will cause an object to speed up or slow down (Newton's 2nd Law). The classroom has available a loaded wagon to which a pulling force can be applied. Ms. Brandt is considering four different approaches to the lesson.

Thinking about how you would want to teach this lesson, of the following, which one is most similar to what you would do?

A. Write a clear statement of Newton's 2nd Law on the board and explain it carefully for my learners. Then I would demonstrate the law by pulling on a loaded wagon with a constant force in front of the class as they observe the motion.

B. Write a clear statement of Newton's 2nd Law on the board and explain it carefully for my learners. I would then have the learners verify the law by pulling on a loaded wagon themselves and confirming what type of motion results.

C. Raise the question of what kind of motion results from a constant force. I would then guide my learners to explore the question themselves by pulling on a loaded wagon and observing what happens. From the evidence they would then propose a possible law.

D. Raise the question of whether there is any relationship between force and motion. My learners would then be free to explore this safely in the lab. Afterward we would have a class discussion of their findings.

ITEM 6: Temperature and solubility

Ms. Maluleke's 7th graders have learned that sugar becomes more soluble in water as the temperature increases. She has demonstrated this by putting the same amount of sugar into cold and hot water in two graduated cylinders: after shaking, any undissolved solid settles at the bottom and one can compare this in the hot and cold water cylinders. Now she wants her learners to learn that not all solids respond the same way. For example, the solubility of salt does *not* increase with temperature. Graduated cylinders, salt, and cold and hot water are available.

Thinking about how you would teach, of the following, which one is most similar to how you would conduct this lesson?

A. I would ask if the class thinks that all solids dissolve better in hot water. What about salt? I would ask them to design an experiment to test whether the amount of salt that dissolves depends on water temperature, then find out using graduated cylinders, salt, and cold and hot water.

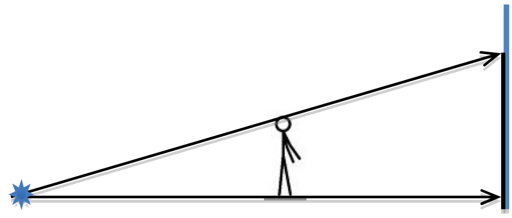
B. I would explain that while they found that heat increases the solubility of sugar in water, not all solids behave the same way. I would demonstrate this by using the graduated cylinders, salt, and cold and hot water.

C. I would explain that while they found that sugar is more soluble in hot water, not all solids behave the same way. I would then have them verify this in the lab, providing clear instructions to ensure they do it correctly, e.g. to use the same amount of salt in each cylinder.

D. I would give my class sets of graduated cylinders, sugar, salt, and cold and hot water, and ask them if they could find out anything interesting using this equipment and materials. Later, we would discuss their ideas.

ITEM 7: Light and shadows

Ms. Adams's third grade learners have learned that light travels in a straight path and that shadows arise when an object blocks light. Ms. Adams wants her learners to be able to *apply* these ideas to make predictions about shadow behaviour.



She turns out the main room lights, and has one child Sam stand in the light from a lamp on the floor, casting a shadow on the wall. Learners draw ray diagrams in their notebooks showing how Sam's shadow is being formed. Ms. Adams says that once we understand about shadows we can *predict* what will happen to the shadow if Sam moves further from the lamp.

Thinking about how you would teach, how would you suggest Ms. Adams continue this part of the lesson?

A. Ask each learner to think and make their own prediction of what will happen to the shadow, based on what they have learned, and explain with a ray diagram. Then have Sam move to check their predictions.

B. Ask learners to predict what will happen to the shadow, and make a ray diagram, but give no further guidance. Then have Sam move, and if there is a discrepancy let the learners discuss and resolve.

C. Draw a ray diagram on the board to show that the shadow was smaller when Sam is further from the lamp. Then have Sam move to confirm this prediction.

D. Have learners follow her directions to make a second diagram in their notebooks with Sam further away, and point out to them how this shows the shadow will come smaller. Then have Sam move to confirm the prediction.

ITEM 8: Photosynthesis

1	2	3	4	5	6

Ms. Hamid has been teaching her 8th grade learners about photosynthesis, and in particular that chlorophyll in plant leaves is light-induced. She then has her learners conduct an activity to illustrate this. She has placed fast-growing seedlings where they are exposed to different levels of light intensity. The learners observe the growing plants over several days and estimate the amount of chlorophyll using a colour chart to record leaf colour. They record their data in their science notebooks and on a classroom data table. On the last day, Ms. Hamid reviews the role of light in chlorophyll production as illustrated by the activity.

Thinking about how you would teach this topic, of the following, which is the best evaluation of her lesson?

A. The instructional sequence would be better if reversed; i.e. have learners do the plant observations first, showing that chlorophyll is light-induced, after which Ms. Hamid can explain the process more fully.

B. Ms. Hamid begins appropriately with an explanation of the concepts she wants the learners to learn. This being so, it is not clear that the activity is needed, especially since it requires so much class time.

C. This is a good lesson design overall because Ms. Hamid begins with an explanation of the concepts she wants the learners to learn followed by an experimental activity for learners to confirm that chlorophyll production is light-induced.

D. Ms. Hamid's approach is too pre-organized and prescriptive. It would be better for learners themselves to decide how to set up plants and lights, see what happens, and figure out a way to compare chlorophyll production in the leaves.

ITEM 9: Rain and water flow

Ms. Walters wants to start teaching her 2nd grade learners about water movement and bodies of water on Earth, i.e., to understand that when rain falls on Earth the water flows downhill into bodies of water (streams, rivers, lakes, oceans), or into the ground.

Thinking of how you would design a lesson for your learners, which of the following approaches would you suggest Ms. Walters take?

A. Project a diagram showing rain falling onto the earth, and water running downhill to form streams, rivers, lakes and oceans, with some going into the ground. Then go over each aspect carefully while pointing to it on the diagram, taking questions along the way.

B. Provide a box of soil at each bench and have groups shape landscapes in it with hills and valleys. Have them suggest what might happen if they sprinkle water on it to represent rain. Then have them try it out, report their observations and relate that to what happens on Earth.

C. Have learner groups shape soil into hills and valleys and sprinkle water onto it, but don't tell them in advance what it is about or what to focus attention on. Have them report what they observe happens and suggest if this is similar to anything on Earth.

D. Tell learners that rain falling on the ground will flow downhill to form streams, rivers, lakes and oceans. Demonstrate this with a model: a large shallow box of soil, shaped into hills and valleys. Learners watch as she sprinkles water from the spray nozzle of a watering can, and asks them to notice how it flows downhill to form streams and then ponds.

ITEM 10: Incorrect volume measurement

Mr. Cobb's 8th grade learners have been asked to devise a method of finding the density of this granular substance, in order to suggest what the mystery element might be. One group of learners decides to measure the volume of their granular sample by pouring the sample dry into a measuring cylinder. Unlike a water displacement method, their method will give a wrong value for the actual volume of granules (because it includes air spaces).

Thinking about how you might teach, how do you think Mr. Cobb should deal with this?

A. Tell them immediately that this method will give the wrong volume because of air spaces in the sample, and that they should use the water displacement method instead.

B. Before they go any further, ask them to think about their volume measurement, and prompt the idea of air spaces between granules if necessary. Once they recognize the problem ask them to think of another method, then continue.

C. Let them go through with the whole experiment using their method, calculating a density value and suggesting a possible element. Then point out the anomalous result, ask them to think again and have them re-do the experiment after identifying the problem.

D. Let them go through with it their way, calculating a (wrong) density value and suggesting a possible element. But do not have them repeat the experiment correctly; rather have them put their anomalous result down to 'experimental error.'

Appendix F: EQUIP Protocol

EQUIP
(Electronic Quality of Inquiry Protocol)

Complete Sections I before and during observation, Sections II and III during the observation, and Sections IV-VII immediately after the observation. If a construct in Sections IV-VI absolutely cannot be coded based on the observation, then it is to be left blank.

Observation date: _________ Time start:_______ Time end: ______ Observer: ______________________________

School: _________________________ District: ___________________________ Teacher: ______________________________

Course: _______________________

I. Descriptive Information

A. Teacher Descriptive Information:

1. Teacher gender ____ Male (M), Female (F)
2. Teacher ethnicity ____ Caucasian (C), African-American (A), Latino (L), Other (O)
3. Grade level(s) observed ____________4. Subject/Course observed ______________________
5. Highest degree ___________________ 6. Number of years experience:___________ 7. Number of years teaching this content ______

B. Student/Class Descriptive Information

1. Number of students in class: ____________
2. Gender distribution: _____ Males _____Females
3. Ethnicity distribution ______Caucasian (C) ______ African-American (A) ______ Latino (L) ______Other

C. Lesson Descriptive Information

1. Is the lesson an exemplar that follows the 4E x 2 Instructional Model? (PDI exemplar, non-PDI exemplar, non-exemplar)
2. Working title for lesson:
3. Objectives/Purpose of lesson: Inferred (I), Explicit (E) ___:
4. Standards addressed: State (S), District (D), None Explicit (N) ___ :

II. Time Usage Analysis

Time	Activity Codes	Organization Codes	Student Attention to Lesson Codes	Cognitive Codes	Inquiry Instruction Component Codes	Assessment Codes
0-5						
5-10						
10-15						
15-20						
20-25						
25-30						
30-35						
35-40						
40-45						
45-50						
50-55						
55-60						
60-65						
65-70						
70-75						
75-80						
80-85						
85-90						

Activity Codes—facilitated by teacher

0. **Non-instructional time**—administrative tasks, handing back/collecting papers, general announcements, time away from instruction
1. **Pre-inquiry**—teacher-centered, passive students, prescriptive, didactic discourse pattern, no inquiry attempted
2. **Developing inquiry**—teacher-centered with some active engagement of students, prescriptive though not entirely, mostly didactic with some open-ended discussions, teacher dominates the explain, teacher seen as both giver of knowledge and as a facilitator, beginning of class warm-ups
3. **Proficient inquiry**—largely student-centered, focus on students as active learners, inquiries are guided and include student input, discourse includes discussions that emphasize process as much as product, teacher facilitates learning and students active in all stages, including the explain phase
4. **Exemplary inquiry**—student-centered, students active in constructing understanding of content, rich teacher-student and student-student dialogue, teacher facilitates learning in effective ways to encourage student learning and conceptual development, assumptions and misconceptions are challenged by students and teacher

Organization Codes—led by teacher

- W Whole class
- S Small group
- I Individual work

Student Attention to Lesson Code—displayed by students

- L **Low attention**, 20% or fewer attending to the lesson. Most students are off-task – heads on desks, staring out of the window, chatting with neighbors, etc.
- M **Medium attention**, between 20-80% of students are attending to the lesson.
- H **High attention**, 80% or more of the students are attending to the lesson. Most students are taking notes or looking at the teacher during lecture, writing on the worksheet, most students are volunteering ideas during a discussion, most students are engaged in small group discussions even without the presence of the teacher.

Cognitive Code—displayed by students

0. Other-e.g. classroom disruption, non-instructional portion of lesson, administrative activity
1. Receipt of knowledge
2. Lower order (recall, remember, understand) and/or activities focused on completion exercises, computation
3. Apply (demonstrate, modify, compare) and/or activities focused on problem solving
4. Analyze/Evaluate (evidence, verify, analyze, justify, interpret)
5. Create (combine, construct, develop, formulate)

Inquiry Instructional Component Code—facilitated by teacher

0. **Non-inquiry**: activities with the purpose of skill automation; rote memorization of facts; drill and practice; checking answers on homework, quizzes, or classwork with little or no explanation
1. **Engage**: typically situated at the beginning of the lesson; assessing student prior knowledge and misconceptions; stimulating student interest
2. **Explore**: students investigate a new idea or concept
3. **Explain**: teacher or students making sense of an idea or concept

Extend: [Extend is important but is not coded as such because it typically is a new Engage, Explore, or Explain]

Assessment Code—facilitated by teacher

0. **No assessment observed**
1. **Monitoring** (circulating around the room, probing for understanding, checking student progress, commenting as appropriate)
2. **Formative assessment** (assessing student progress, instruction modified to align with student ability) or **Diagnostic assessment** (checking for prior knowledge, misconceptions, abilities)
3. **Summative assessment** (assessing student learning, evaluative and not informing next instructional step)

III. Lesson Descriptive Details		
Time (mins into class)	Classroom Notes of Observation	Comments

IV. Instructional Factors					
Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
I1.	Instructional Strategies	Teacher predominantly lectured to cover content.	Teacher **frequently lectured** and/or used demonstrations to explain content. Activities were **verification only**.	Teacher **occasionally lectured**, but **students were engaged in activities** that helped develop conceptual understanding.	Teacher occasionally lectured, but students were engaged in investigations that **promoted strong conceptual understanding**.
I2.	Order of Instruction	Teacher explained concepts. Students either did not explore concepts or did so only after explanation.	Teacher asked **students to explore concept before receiving explanation**. Teacher explained.	Teacher asked students to **explore before explanation. Teacher and students explained**.	Teacher asked students to explore concept before explanation occurred. Though perhaps prompted by the teacher, **students provided the explanation**.
I3.	Teacher Role	Teacher was center of lesson; rarely acted as facilitator.	**Teacher was center** of lesson; **occasionally** acted as **facilitator**.	Teacher **frequently** acted as facilitator.	Teacher **consistently and effectively** acted as a facilitator.
I4.	Student Role	Students were consistently passive as learners (taking notes, practicing on their own).	**Students were active to a small extent** as learners (highly engaged for very brief moments or to a small extent throughout lesson).	**Students were active as learners** (involved in discussions, investigations, or activities, but not consistently and clearly focused).	Students were **consistently and effectively active as learners** (highly engaged at multiple points during lesson and clearly focused on the task).
I5.	Knowledge Acquisition	Student learning focused solely on mastery of facts, information, and/or rote processes.	Student learning focused on **mastery of facts** and process skills without much focus on understanding of content.	Student learning required **application of concepts** and process skills in new situations.	Student learning required **depth of understanding** to be demonstrated relating to content and process skills.

V. *Discourse Factors*

Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
D1.	Questioning Level	Questioning rarely challenged students above the remembering level.	Questioning rarely challenged students above the **understanding level**.	Questioning challenged students **up to application or analysis levels**.	Questioning challenged students at various levels, **including at the analysis level or higher; level was varied to scaffold learning**.
D2.	Complexity of Questions	Questions focused on one correct answer; typically short answer responses.	Questions focused **mostly on one correct answer**; some open response opportunities.	Questions **challenged students to explain, reason, and/or justify**.	Questions required students to explain, reason, and/or justify. **Students were expected to critique others' responses**.
D3.	Questioning Ecology	Teacher lectured or engaged students in oral questioning that did not lead to discussion.	Teacher occasionally **attempted to engage students in discussions** or investigations but was not successful.	Teacher **successfully engaged students** in open-ended questions, discussions, and/or investigations.	Teacher **consistently and effectively engaged students** in open-ended questions, discussions, investigations, and/or reflections.
D4.	Communication Pattern	Communication was controlled and directed by teacher and followed a didactic pattern.	Communication was **typically controlled and directed by teacher** with occasional input from other students; mostly didactic pattern.	**Communication was often conversational** with some student questions guiding the discussion.	Communication was **consistently conversational with student questions often guiding the discussion**.
D5.	Classroom Interactions	Teacher accepted answers, correcting when necessary, but rarely followed-up with further probing.	Teacher or another student **occasionally followed-up student response** with further low-level probe.	Teacher or another student **often followed-up response** with engaging probe that required student to **justify reasoning or evidence**.	Teacher **consistently and effectively facilitated rich classroom dialogue** where evidence, assumptions, and reasoning were challenged by teacher or other students.

VI. *Assessment Factors*

Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
A1.	Prior Knowledge	Teacher did not assess student prior knowledge.	Teacher assessed **student prior knowledge but did not modify instruction** based on this knowledge.	Teacher assessed student prior knowledge and then **partially modified instruction** based on this knowledge.	Teacher assessed student prior knowledge and then **modified instruction** based on this knowledge.
A2.	Conceptual Development	Teacher encouraged learning by memorization and repetition.	Teacher encouraged **product- or answer-focused** learning activities that **lacked critical thinking**.	Teacher encouraged **process-focused** learning activities that **required critical thinking**.	Teacher encouraged process-focused learning activities that involved **critical thinking that connected learning with other concepts**.
A3.	Student Reflection	Teacher did not explicitly encourage students to reflect on their own learning.	Teacher **explicitly encouraged** students **to reflect** on their learning but only at a minimal **knowledge level**.	Teacher **explicitly encouraged** students **to reflect** on their learning at an **understanding level**.	Teacher consistently encouraged students to reflect on their learning at multiple times throughout the lesson; **encouraged students to think at higher levels**.
A4.	Assessment Type	Formal and informal assessments measured only factual, discrete knowledge.	Formal and informal **assessments measured mostly factual, discrete knowledge**.	Formal and informal assessments **used both factual, discrete knowledge and authentic measures**.	Formal and informal assessment methods **consistently and effectively used authentic measures**.
A5.	Role of Assessing	Teacher solicited predetermined answers from students requiring little explanation or justification.	Teacher **solicited information from students to assess understanding**.	Teacher solicited explanations from students to assess **understanding and then adjusted instruction accordingly**.	Teacher frequently and effectively assessed student understanding and adjusted instruction accordingly; **challenged evidence and claims made; encouraged curiosity and openness**.

VII. Curriculum Factors

Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
C1.	Content Depth	Lesson provided only superficial coverage of content.	Lesson provided **some depth** of content but with **no connections made to the big picture**.	Lesson provided depth of content with **some significant connection** to the big picture.	Lesson provided depth of content with **significant, clear, and explicit connections** made to the big picture.
C2.	Learner Centrality	Lesson did not engage learner in activities or investigations.	Lesson provided **prescribed activities** with anticipated results.	Lesson allowed for **some flexibility during investigation** for student-designed exploration.	Lesson provided **flexibility for students to design and carry out** their own investigations.
C3.	Integration of Content and Investigation	Lesson either content-focused or activity-focused but not both.	Lesson provided poor integration of content with activity or investigation.	Lesson **incorporated student investigation that linked well with content**.	Lesson **seamlessly integrated the content and the student investigation**.
C4.	Organizing & Recording Information	Students organized and recorded information in prescriptive ways.	**Students had only minor input as to how to organize and record information**.	Students regularly organized and recorded information in **non-prescriptive ways**.	Students organized and recorded information in **non-prescriptive** ways that allowed them to **effectively communicate their learning**.

*VIII. Summative Overviews**		*Comprehensive Score***
Summative view of Instruction		
Summative view of Discourse		
Summative view of Assessment		
Summative view of Curriculum		
Overall view of Lesson		

Appendix G: Interview schedules

Interview schedule: Teacher Background

1. Please describe your teaching experience

a. Number of years taught

b. Number of schools taught at

c. Subjects and years each taught

2. What is your education background (undergraduate and graduate degrees)?

3. Please describe your science content background.

a. Previous work experience

b. Previous laboratory experiences

Interview schedule: General teaching views

1. How do you tell if you leaners are learning during your lessons?
2. What would you define as effective teaching of science?
3. What is the purpose of teaching science?
4. Can you describe for me what you call an ideal science lesson?
5. What do you think are the teachers' roles in a science lesson?
6. What do you think are the learners' roles in a science lesson?
7. What advice will you give a secondary school teacher about teaching science?

Interview schedule: Investigations

1. What do you understand by the inquiry-based teaching?
2. Please describe a lesson where you have employed this approach.
3. Do you believe inquiry has benefit for science learning?
4. What do you consider to be some of the benefits of inquiry-based teaching?
5. How often do you implement this approach in your teaching?
6. What are some of the challenges you experience in this approach?
7. What is your competency in adopting inquiry-based teaching?
8. Are you confident in using this approach?
9. How can I support you in developing your expertise in teaching inquiry?
10. Have you received any professional development in inquiry?

11. To what extend have you managed to implement inquiry-based teaching in your classroom

12. What have you done well so far as far as inquiry-based teaching is concerned?

13. What do you think you need to improve on?

14. What are the challenges you face when implementing inquiry-based teaching

15. How best do you think these issues you raised can be addressed, especially the ones that involve you and your classroom practice?

16. When given support what are some of the areas of your practice you think need urgent attention especially when it comes to inquiry-based teaching?

17. What are your suggestions if ever these challenges are to be addressed?

Appendix H: Sample of interview transcripts on teacher background

Interview transcript for Mr. Kapok

R: What I want to now is the details of your educational background.

T: My primary school was at rural areas. The school was starting from grade R to Grade 9. During our time, that school was a very good primary school in the area. As a results many people who are successful in my community did their grade R to 9 in that school. It was a good school because those teachers were active. All teachers in that school were active, they were good. They delivered in a good way.

R: Any teacher you admire.

T: It is my Maths teacher. That one of Maths we had morning class every day. My science teacher she was also good, but she can't make it to that one of Maths. She was doing experiments and practical with us at primary school. All subjects had teachers in that school. At high school, a very poor high school. The school never obtained more than 50% pass rate in grade 12 since 2002. In that school the percentage of learners passing mathematics is less than 30%. When I was doing grade 12 only 9 out of 111 learners passed Maths in that school. The parents in the community are not educated. They cannot do anything about that. The principal will just tell them that it's my school. So they cannot tell him anything but many learners are failing there; good learners from good primary schools when they go there they just fail grade 12. For you to pass in that school you must be a hard worker like me. I was studying at night. If you don't study on your own you won't pass.

R: The science one?

T: The science one, it's me who was stupid. That one was a very good teacher. He taught me everything. He always finish the syllabus early, do thorough revision and giving us homework. He will demand us to finish given question papers. We will do those question papers at home. There was no way you will say you don't understand physical science because he was always there at school for us. If I can be an educator like that educator, then it will be good for learners because that one changes the life of learners.

R: Then the laboratories?

T: We had apparatus but they were few. We were doing all those experiments of diffractions.

R: It was from which year to which year?

T: I started primary in 1998. After high school it was university. Yes. The problem in that University is these things of Strikes. Sometimes they can affect learning of Students. Sometimes they can strike for about 2 months, the whole month we end up not learning. Sometimes they say we don't' want this lecturer and they will just change that lecturer because they are failing. I remember the one who taught us Calculus. That one was very good, I used to pass his Maths with distinctions but others were failing that Maths and we were 273 only 58 passed that Maths. So they decided to say let's change this lecturer because this one we don't get him when he is teaching. The degree was Bachelor of Education in Science, four year degree with teaching practice. In level 2 you go and observe for two weeks you sit down and write down everything that you observe from that educator. The good things and bad things. You complete the file and submit the file. The teaching practice was 6 weeks then research, 4 months in year 4.

R: You did a research?

T: Yes like you come with a topic. Like my topic was the poor performance of Physical Sciences in Grade 12 in one district. I was researching the causes and the solutions of that problem of poor performance and what are those schools and what are the main factors of poor performance. What I found there is there are no teachers in those schools. The teacher who is teaching Mathematics grade 10 – 12 is also teaching Physical Sciences grade 10 – 12. In 2014 I produced 100% pass rate in physical science. Even if I was teaching at a rural school. I produced 58% pass rate in 2015. I came to teach in Gauteng in 2016. That is why I am praying that this years these learners produce 100% so that they can see. Here it's very difficult to teach, you are teaching these learners and some person who is supposed to motivate these learners demotivate them. I like teaching, I don't do teaching because of money. I like teaching, if you can see when I am teaching the learners teaching becomes interesting.

Appendix I: Sample of interview transcript on general teaching views

Interview transcript for Mr. Moloku

R: How do you tell if leaners are learning during your lessons?

T: By their response to my questions. By the leaners bodily expressions.

R: What would you define as effective teaching of science?

T: Teaching whereby leaners will be able to grasp the scientific concepts and be able to correctly respond to questions that involve the concepts.

R: What is the purpose of teaching science?

T: To foster technological development through critical scientific thinking.

R: Can you describe for me what you call an ideal science lesson.

T: A lesson where scientific concept are practically discovered and hence grasped by leaners.

R: What do you think are the teacher's roles in a science lesson?

T: To help guide learners to discover scientific concepts.

R: What do you think are the learners' roles in a science lesson?

T: To discover scientific concepts .To think critically

R: What advice will you give a secondary school teacher about teaching science?

T: Be a facilitator, a guide, and a helper to the learner, be practical and be prepared fully.

Appendix J: Sample of interview transcript on investigations

Interview transcript for Mr. Charles

1. **How do you find investigation in physical science?**

Investigations are part of experimental work where learners have to carry out a practical in order to ascertain certain conclusions about science. In that experiment there is nothing new that the learners will be trying to find out except to repeat what has been done by scientist and verify that it is true and it does happen that way. In physical sciences investigations are usually hampered (like in our former black schools) by the availability of material and the exposure of learners to the method of scientific inquiry and scientific investigation. Usually it is like it's strange to them that you are going to experiment on this and that. They do help a lot in trying to concretize information the learners have learnt theoretically in class. They are an integral part of learning and teaching of science.

2. **Do you have any other investigations that do not connect with the practical?**

We have what we call a research. They go and find out information about certain aspects of science and they write a report on that, same like you are doing I don't think you will go into the lab, but you can carry out interviews. For example one research was on biofuels some years ago; there is no experiment, you go on to the internet and download what is the government's regulation about biofuels, which companies are involved, which countries are using it, what are the benefits, what are the pros and cons.

3. **How has investigations helped to achieve your goals as a physical science teacher?**

As I was indicating that the investigations give a learner a chance to prove the theories, laws of science. And sometimes to see in reality things that we are talking about. To see those things in practical induces in the learner a copy of that information that is not easily erased.

4. **How do you use investigations in your teaching of physical sciences?**

There are two aspects to that, the first one is the practical itself, that is the hands-on where learners get a hand-out beforehand and they go and probably read and acclimatize with the method, then they come back and do the practical or the investigation whichever. Then because of the limitations in time, space or material we then come to what we call a practical investigative questions where in any examination it's a must that such a question is there. When you teach you take such questions where a practical is put in theory and then questions or conclusion must be drawn from that. That practical can have a variety of scenarios, in some practical you can give them information on the results, so a learner should look at patterns in the results, look at systems in those results, look at what is usual in those results. Then from there you make your conclusion based on the variables that are there and the repetitions that are in those results. It does help, because (i) it forms part of the examination and (ii) out of one practical that you can do you can make a lot of practical questions or assimilate those practical questions in any theory or theoretical situation, because you cannot carry a practical for every aspect.

5. **What are the challenges you face when your learners are doing investigations?**

The challenges have to do with material resources like our labs were stocked for NCS and CAPS is now bringing new practical that require new types or chemicals or substances. I will give you an example of a practical which needs a nail polish remover we never had that in our labs. The second one is the base of the learner from grade eight and nine, where they have never touched a test-tube in a practical, where educators did not do the practical and you expect the learners to be familiar on the use of these apparatus. Thirdly we have also a language barrier, our learners are second speakers of English and hand-outs and everything is done in English, sometimes that English is not understood by learners. Finally, we have a question of attitude this laser fare attitude on our learners-where they say life goes on, they don't see the importance of practical work in physical sciences.

6. **Do you design investigations for your learners or you only use readymade investigations from somewhere**

Because of the system and policy that we use now, we are provided, this is a must, if it's for formal assessment, but as an educator you can improvise sometimes or change the way that practical has been done especially the informal ones. The formal ones you have to stick to them as they are, you have no choice unless otherwise like you are in short of something drastically and then you can justify why you deviated from that; that is policy they have to do the practical as it is.

7. **Who normally provides these investigations?**

They are provided by the province through the district.

8. **What kind of support do you give your learners when doing investigations in physical science?**

Provision of the hand-outs, you explain aspects of the practical that are important for example safety and then observations, how to record their results. You tell them the key points to watch for in the practical. In a practical a lot of things can happen, and a learner can tell you things were like this, which was not the focal point of that practical so you sort of blinker them or focus them on the issues that they must watch out. You also provide them with the materials that they require for the practical; you also give them the format of the report writing. After the practical they write a draft which you must quickly check and confirm that it's okay. It's like semi-marking that work before they submit the final work, it does help in that if the learner has gone wrong somewhere they can correct and understand better and get better marks for their practical.

9. **What are the challenges you are facing as an educator when it comes to investigations in physical science?**

The change in syllabus calls for new materials, as a school our labs have been vandalized to an extent that we cannot use them. We also have some labs that have been taken over by some other departments and are used for learning areas other than science. We also have a slight challenge in the competence of educators; where an educator is not interested in science or has limited knowledge on science especially practical. We also have a challenge in terms of training when syllabus are changed or when certain aspects of science are introduced the trainings are done haphazardly and not in depth. Usually not all teachers attend and those that attend are not the ones that are going to teach the subject and they have to develop others and that does not happen. It's like the snowball effect where the information meant for these educators does not finally come to them in full.

10. **Do you think you can do better with extra support from outside?**

Very well. Support wherever it comes from is welcome. If the aim of that support is the same as what you would get from school is welcome. We can welcome support in form of lab equipment or chemicals or workbooks, even training educators.

11. **What do you understand by inquiry based-teaching?**

It is a type of teaching where you don't provide ready-made answers to learners. You let them experiment, investigate, and come up with their own conclusions about certain concepts in science. It's not like spoon feeding them, they have to experiment and inquire. However you must direct them. Remember in any inquiry there can be a lot of answers or a lot of observations made. You should make sure you direct your learners to observe those aspects of the inquiry that you want to have an impact on their understanding of science.

12. **Please describe a lesson where you have employed this approach?**

Talk of Boyles law for example, Boyles law is under ideal gases, where variation in volume and pressure at constant temperature should be observed. You provide the learners with the Boyles equipment apparatus and then they increase pressure and they can read the volume of the gas. After that then you ask them when we were increasing pressure what was happening to the volume of the gas. They should know that the volume of the gas was decreasing. So increase in pressure, decrease in volume. Then you say we can come up with a law therefore that says if you increase pressure you can reduce volume. That is Boyle’s law. Sometimes these learners are so clever that by the time you talk about Boyles they just ‘google’ and find the law, but if you want them to verify now, you don’t give them the Boyles law first, but give the experiment first. Is it true that if you increase pressure the volume decreases?

13. **Do you believe inquiry has benefit for science learning?**

Yes it has, because that’s the only way we can discover things that we don’t know. Just imagine the scourge of HIV infection if we don’t use inquiry to find things that we don’t know, how can we get medication. When you get result in science you look for the obvious, you look for the patterns or you look for repetitions or you can look for the awkward, everything happens like this but once in a while it goes the other way round. Then from there you build up your conclusion to say that once in a while it does this or it is always like this. This is what makes science usable.

14. **What do you consider to be some of the benefits of inquiry-based teaching?**

It develops a sense of independence on the learner, critical thinking, it inspires confidence in the learner because they are actually doing the work themselves, it develops responsibility in the learner, it also develops the intellect of; the desire to find out about most of the science things we have, it has a very good effect on team work and collaboration that sometimes alone you can’t be able to do some of these things, you have to work as a team or with a colleague. It also sharpens the aspects of ability to research on the part of learners. On the part of the educator it gives the educator enough time to assess the learners, by enough time I mean whilst they are doing the experiment the educator is observing and interfering once in a while. You learn better about your learners whilst you are watching them working. Their marks would go up, because since you are watching them it’s unlikely that they will do the wrong things and you keep quiet. You will go and intervene. You don’t intervene by telling them the right things you provoke them until they see. Chances are they will pass better using scientific inquiry than if you were to like say this is what happens, then go and write. They will remember things that they did far much better than things you simply tell them in class.

15. **How often do you implement this approach in your teaching?**

Not quite often because the inquiry approach is time consuming you cannot tell how long it will take them to do that. It's not quite often, once in a while. Let's say twice a term or so.

16. **What are some of the challenges you experience in this approach?**

The fact that its time consuming, also you need resources which might not be available. As an individual I don't have any problem with it, but some other educator may find it difficult in terms of trying to grasp the method itself and say learners are supposed to do A, B, C. It will then depend on the level of educator competence. You have to know how to direct the learners and to make sure that those aspects of the investigation you want them to conclude on are addressed. Since it is time consuming, you might find that some of the learners might like, sort of being idle and lose focus, and then the objective is not achieved. You know they are young and playful, you need to keep them engaged every time.

17. **Are you confident in using this approach?**

That will be a big yes.

18. **How can I support you in developing your expertise in teaching inquiry?**

The area that we might need assistance is to come up with say some form of booklet on scientific inquiry, where you have got samples of practical. Like when you say the experimental question where learners should come up with a conclusion. A booklet of questions where probably a wrong answer would be like difficult for a learner to put, because they will always be some area where they will pick the correct answer. From the work schedule we are stigmatized to say do this. I will give you an example in Life Sciences now they are busy doing an experiment where they have to use celery. If you don't have celery you can use spinach. The results in the end are going to be the same. So you know such things, if you are using celery it's like this if you are using spinach, it's like this. If you don't have this you can use another one, because contextual factors are different, we are not all the same. This celery we had to go to town to buy it because locally you don't find it.

19. **Have you received any professional development in inquiry?**

Inquiry per se No. just like in passing you can use scientific inquiry. Not at a workshop. During ACE methods of teaching, there was this module on methods of learning and teaching of science and inquiry method was there. So it's not a no, but a yes.

20. **To what extend have you managed to implement inquiry-based teaching in your classroom**

If you talk of inquiry when learners are in grade 12 and you started in grade 10. Yes you can tell that you have been somewhere. But at grade ten they are still struggling to find out; what the teacher wants us to do. After a year in grade 11 they start to see the light. In grade 12 I tell you the grade 12 that we have now they know their business. It takes time, it's not a once off thing then you get results.

21. **What have you done well so far?**

Let me start with the positive part, on conclusions, arriving at a conclusion that one I have no problem. Analysing results that is my best area where you can see results then make head and tail of what is actually taking place. A slight challenge, the practical is okay, I have no problem with the practical. The part that is a little bit grey to me is the formulation of the investigative question. If it is a scientific inquiry, it means you don't provide the learners with the method they must bring, but as an educator you must know that they must go like this. If they are options and those options should come into place. This is what I was saying if we have external help we should be given a hand-out that has options on the practical. Let's say if you are talking about Boyes law how can you go about it, or how can we use the same method without a practical but give them a series of questions so that they can come to the same conclusion as if they were doing a practical

22. **What are some of the suggestions on the challenges that are faced when doing practical investigation?**

The first challenge is, ill-equipped labs make life very difficult for a science educator in both human and non-human resources. We don't have, probably we have one or two functional labs. We don't have a lab assistant, the materials are not enough. The second one has to do with time; I don't see myself carrying out a science lessons in thirty minutes, not in thirty minutes but less than thirty minutes. It's a big challenge, besides that you would wish to have an hour at least, in order to be able to carry out some of these things. Like I have said scientific inquiry method is time consuming, it's like Democracy where everyone talks until they don't have anything else to talk. The periods in the time-table allocation, they pose a challenge. The last one, I think this one has to do with the syllabus in Physical Sciences. Physical Sciences is a combination of Physics and Chemistry. It is not accorded the amount of time that goes with the content that has been placed there, you find that guys who are teaching mathematics by the time they write their June examinations they are done with their syllabus, it's impossible for Physical Sciences.

Appendix K: Sample of interview transcript on follow up to pre-POSTT-PS

Interview transcript for Mr Charles

Question 1

R: Why did you leave option A? **(Didactic direct)**

T: This one I find it wrong because, me I am trying to take learners from their common life, from their own context. Mirrors are things that you have in everyday life. So if you take them from those things that they know, then apply or drive them to where they would then understand that there is a law that governs this phenomenon, then it's understood better. Than to start from the top to bottom. This method is starting from top to bottom. Whereas you must drive them from what they know, then say this is the law that controls this phenomenon.

R: Why did you leave option C? **(Open inquiry)**

T: This one for me is like going forward and backwards. There is no mention of the concepts that have to do with light or the law of reflection. It's like you just going in circles. It does not move students from what they know to what they don't know.

R: Why did you leave option D? (**Active direct)**

T: D is the same as A. starting from the top to bottom. It's good for practical for learners to go discovery, rather than to give them the law and say go and discover; what's the point. When they see the connection it will stick much better in their mind, than give them the law and say verify. Even though we know that these laws and what we do in class have been done probably thousands and million times over and over, us we are just repeating to see if this thing does really happen. But then drive them from the simple to the complex or from the known to the unknown.

Question 2

R: Why did you leave option B? (**Active direct)**

T: Look similar these methods, but me I choose A not B, because of the difference in the workbooks and worksheets. In the worksheets, this is an experiment I want to direct students to method of recording that I think is better or best for them. In B the way of recording is of their choice. Here you are talking of grade eights, they are still very naïve on the method of recording. You are trying to build a base of how these learners should record information. So you provide them with a worksheet that is readily made. Grade 11 -12 I will give them an option. By then they should have either picked the proper method as we moved from grade 8, 9 and 10 grades or they would have an idea of variables now. To say if you have the variables on your table you have to record the independent and dependent variables.

R: Why did you leave option C? **(Guided inquiry)**

T: Eighth grade the idea of proposing a method of inquiry or doing an experiment. They are not mature enough. This is what grade 10-12 would do where you would say can you design and use that method. Nowadays for example in CAPS when you say practical investigation that's when you need the learners to come up with their own method, but if it's an experiment you must provide learners with that. It's because of the grade, we are trying to inculcate in them how a good, method, how results can be recorded and how you analyse them. It's not as complex as in grade 10-12. If it was a higher grade I would use this method, but for some experiments.

R: Why did you leave option D? **(Open inquiry)**

T: It is so open, the learners work independently. They do their own method. Experiment of their own, write up, results and conclusion. This one is a high order practical which would need either learners in higher grades than grade 8. Somehow you must check and balance the work that they are doing. You leave students to their own devices – it's too open. It's like you are talking of a university student not high school student.

Question 3

R: Why did you leave option A? **(Guided inquiry)**

T: Mr. Ndlovu is trying to develop an understanding around the working of a thermometer. You draw from the learners what they know about thermometer, they can tell you about thermometers from the hospital, and in the lab and thermometers that can be used to record temperature outside at the weather station. From there because these thermometers they vary according to their use. The lab thermometer is not the same as the clinical thermometer, which is not the same as the other thermometers used somewhere else e.g. industry. Whatever they know you as a teacher you build up from there. This is a little bit confusing. Mystery devices from there you put materials for them to explore. It's like going in circles. You tell the students about the mystery and you divulge the mystery.

R: Why did you leave option B? **(Didactic direct)**

T: This one is too obvious, it's like you want to drag the learners along. There is no input from the learners, you are simply giving them information it's not a good one for scientific inquiry.

R: Why did you leave option D? **(Open inquiry)**

T: This one you are leaving students to their own devices. And if you are leaving students to their own devices anything can be produced. You are looking at time frames here and how much you can achieve in that time. So you do not leave things too open, you put some blinkers, such that they don't go beyond that point. Learners can explore and give you very strange and interesting things, but time is not on our side. You need to cover the syllabus in certain time frames. Just saying do as you wish and come up with the results. You use lotto to say now we have produced a thermometer. I don't think it's good for any grade. But if you have to put blinkers, give learners a chance to contribute to whatever we are going to do and then from there we develop the lesson together.

Question 4

R: Why did you leave option B? **(Guided inquiry)**

T: Here you are doing it for the learners. You need theses learners to develop skills, you don't do it for them. I would rather prepare the juices for them and then put it on their posts and say on your tables you have these chemicals.

R: Why did you leave option C? **(Open inquiry)**

T: This one is too difficult. You say mix- mix and go online and find out. Some of the results you get there would not necessarily be same as the results you see on the internet especially the colours of the juice will depend on the strength of the indicators and concentration of the juice. This one is meant for higher order students. Contextually I am looking at the learner from the townships the idea of going online you are looking for trouble. The technology part of it is not on their side.

R: Why did you leave option D? **(Didactic direct)**

T: It's too common, too obvious, you are doing it for the learners. For this topic I know there two sets of indicators. The artificial ones and the natural ones. after doing the artificial ones I want to contextualise now even in the homes if you see a cabbage changing colour like this that the medium around is like this. This is like extended knowledge that we have these natural indicators. That red cabbage it's in grade 11, I did the experiment, it comes out very nice. I know from previous context when you do indicators that there are artificial indicators and natural indicators. The artificial indicators are the litmus paper, methyl orange, methyl blue, and phenolphthalein. Those are artificial, but then we have natural products which can change colour, so you teach them about these indicators, how they change colours.

Question 5

R: Why did you leave option A? **(Didactic direct)**

You are guiding the learners too much. You would have done this a long time ago. This one is too straight forward.

R: Why did you leave option B? **(Active Direct)**

T: This one you have guided them too much again. Tell them about the law some lessons before and do the experiment separately. Then they can think which one fit.

R: Why did you leave option D? **(Open inquiry)**

T: Now this one leaves learners roaming freely. There is no guidance, its free for all, we need those blinkers.

T: Usually when you do a practical you would have dealt with the theoretical part. It's different from university where you can come from the other end. I chose this one because it involves the learners and they will be knowing the newton's four laws. Examples of the second law will be one in which they are doing the experiment. This one for me is perfect because it involves the learners. On proposing the law they are already guided that it should be between law 1, 2 and 3. Then from the results then they will say which one will fit in.

Question 6

R: Why did you leave option A? **(Guided inquiry)**

T: Here we have carried out the experiment and these are now exceptions. I think I would have gone for A. Since they know how to test solubility already. A would have been better.

R: Why did you leave option B? **(Didactic direct)**

T: This one you will be doing it for the learners. You have done for the sugar now let them do it on their own.

R: Why did you leave option D? **(Open inquiry)**

T: You are leaving learners to their own devices. It's too open.

Question 7

R: Why did you leave option A? **(Guided inquiry)**

T: This one for me it's rather too difficult for the learners, you want to guide their observation to particular aspects of the experiment. You are giving two tasks in one. You must give results for this one then predict.

R: Why did you leave option B? **(Open inquiry)**

T: This one again it's like you are withdrawing too much.

R: Why did you leave option C? **(Didactic direct)**

T: You are giving everything here.

Question 8

R: Why did you leave option A? **(Guided inquiry)**

T: The instructional sequence will be better if reversed. Have the students to do the plant observation first. You are not taking learners from what they know to what they don't know.

R: Why did you leave option B? **(Didactic direct)**

T: The time for the experiment differs with what you are investigating. This is a life sciences experiment and things don't happen in seconds or hours, the growth of a plant takes time.

R: Why did you leave option D? **(Open inquiry)**

T: It becomes too complex for the learners. D is too complex for the learners.

Question 9

R: Why did you leave option A? **(Didactic direct)**

T: It's like you are just directing the learners.

Participant change their mind to B.I think I would have gone for B. B is okay, though it is similar to the one I chose, but the only difference which C is you don't tell them what to focus their attention on.

R: Why did you leave option C? **(Open inquiry)**

T: I won't choose C because it does not direct learner's attention to particular aspects. It is important to direct them, than just to leave them to their own devises.

R: Why did you leave option D? (**Active Direct)**

T: This one is like you are dragging the learners. You are telling them everything.

Question 10 (Choice B-active direct)

R: Why did you leave option A? **(Didactic direct)**

T: You are directing them from the onset, this one doesn't work. Let them inquire

R: Why did you leave option C? **(Guided inquiry)**

T: This one no. it is the opposite of A. why waste time by telling them to go on and on.

R: Why did you leave option D? **(Open inquiry)**

T: This is not worth it. If you can correct the mistake do so. Experimental error is usually placed where you have very little control of sources of error. What you can do is to minimise error not to eradicate it. In this you can eradicate it.

Appendix L: Sample of interview transcript on post lesson stimulated recall discussion

Interview transcript for Mr Moloku

R: You started by a review of the previous day lesson on reflection. Can you give me a brief outline of your objectives for the introduction?

T: It was a recap, trying to see if the leaners remember or understood what we did in the previous lesson which is supposed to link to the lesson of the day.

R: Do you have any misconception that you know about the topic refraction, that leaners are likely to bring into your lesson.

T: I don't know whether it's a misconception, they usually confuse the two refraction and reflection. They normally confuse angle you know that it must be the angle between the normal and the ray if they are given the other one, they forget. I don't know whether they forget or confuse. They do not subtract so that they get the other one. Usually they get that one wrong.

R: In my first interview you told me that you do investigations when introducing or consolidating a topic did I capture that correctly.

T: I think it's correct.

R: Does it mean that in the middle of the lesson you don't use investigations or you sometimes use them as well.

T: I may use them.

R: When I observed your lesson you used the investigation when introducing refraction, what were your objectives

T: The objectives were to make them observe the effects of refraction on their own. As they see the two, they will discover the effects of refraction

R: What else

T: That will now form the part of my lesson so that I can be able to introduce all the concepts that will have to do with refraction basing on those activities.

R: Does it mean you did not expect anything more than observation from the learner.

T: I expected them to observe, I expected them to discover that there is something happening that would lead me to explain that whatever they are seeing is due to refraction. As they do the investigation they should be able to develop scientific skills for them to carry out experiments, to also give them some confidence and also their interest. You will realise that they are more involved when doing an activity than when you just talk.

R: What does the word involve mean to you. Can you give the exact thing?

T: So that they participate in the lesson. So that they feel they are part of the lesson by contributing either to the setup of the apparatus, the carrying out of the investigation. Contributing to the developing of the lesson and concepts.

R: Do you sometimes assess some of the skills acquired in the practical work.

T: I observed them grow. Give them opportunity to ask if I see anything I can ask, to probe to see if they understand what they are doing.

R: Do you trace this development of skills?

T: It is possible. The way I treat grade 10 is different from the way I treat grade 11 and 12. In 11 & 12 they have been doing things in 10 when I was guiding them, but in 11 & 12 I give them some freedom.

R: Here you gave them a method, and allowed them to observe, after you started teaching. Why didn't you allow them to proceed and write their observation, analyse and make a conclusion?

T: The major thing there is time constraints. If u gave them that freedom it will take you longer than you expect. The lesson has a time frame. The major reason is the time frame.

R: If time is affecting the steps, why would you opt to end at observing? Why did not end at manipulation, then you tell them?

T: At least it easier when they have observed. What they have seen becomes your spring board, and then you take off from there. If you observe for them, then it's more of challenge. Let them observed it will be easy to introduce and from what they have seen I can now introduce my concepts through explanation of what they observed

R: if you have all the time in the world were you going to allow them to do all the steps.

T: If time was there I think that's the best way the learner can understand concepts. The best way that can add to their scientific knowledge, because they will have observed, analysed their own. They come with their own conclusion. When you now correct them, they will learn I think and I believe that if time was available that will be the best method to make them understand.

R: Is it not possible for you to do one activity instead of two like you did in the previous lesson, then it will not require a lot of time.

T: Maybe, but I think even when it's one it would still require more time for them to get to the conclusion. Giving them two at least they will know that it was not just coincidence. If I had time I could have done more, so that they see the many times reflection has occurred, but however it would also work if I take one and make sure the go through all the stages, but I think even that one to follow them to do from start to end within the hour lesson is not possible.

R: Which stage of the investigation is really time consuming.

T: The carrying out of it, analysis and conclusion.

R: What could be the reason why they could take time to analyse the data.

T: Remember they are meeting this for the first time, they are also in a group and I think that process of coming up with something concrete to say this is what is happening will require time.

R: What will be your role as a teacher in that case?

T: Then I would ask or probe if I see that they are struggling with this, then I probe so that they have some direction or may sort of guide them.

R: Can I agree with you that analysis time can be reduced with support from the teacher.

T: I agree that would help.

R: Let's say you have given support on analysis can they draw the conclusion on their own.

T: They can conclude, but there are some I think especially in the case of refraction cannot come up with Snell's law. They will come up with certain conclusion that you can make use of to arrive to Snell's law.

R: The practical itself has some things that they learn. Are you planning for these extra skills?

T: I may not plan for them, but I believe they are inherent in the carrying out of the experiment.

R: Can it be possible for you to do a practical?

T: Yes, I would do that. I know in doing that there some skills that will develop that will help them to discover the concepts and many other skills.

R: Help with the many other skills you have mentioned

T: 1. to manipulate apparatus

2. Taking measurements or readings

3. Recording observation

4. being able to discuss these ideas with their peers.

R: Can we agree that a practical can be of more benefit if we increase the number of steps that they participate

T: Yes

R: I think I need to give you the EQUIP observation tool so that the next time you develop your lesson you may make use of it.

T: I think it will be important to check the misconception that leaners have about what you are about to teach.

Appendix M: Sample of interview transcript on follow up to post-POSTT-PS

Interview transcript for Mr. Moloku

R. Can you explain to me why you have shifted in each of the questions 3,4,5,7 and 9?

T: Question 3

In C I can see that there is no exploring by the learner which I realize it's something that learners should actually do. Exploration develop some of their scientific skills like setting up the apparatus, observing, reporting and also as they work together, they develop the communication skills.

Question 4

C here is learner-centered. If you realize in B the teacher is pouring while the learners are watching, are making observation. C involves the learners in doing the activities themselves, it goes back to exploring, helping them to set up the apparatus, interacting with the apparatus, make observations and recording their observations. The teacher is giving some minimal guidance to the learners so that they do not go astray for reasons of time constraints. You know that when you do this you don't have all the time. If you guide them at least that will help to control your time.

Question 5

These are almost the same. I am regarding this as guidance that I am giving to my learners so that they have direction in what they do. Then also guide them to explore. The idea of exploring is in both, but is more in C, which I believe it help the learners to have direction, wherever they get stuck the teacher will be there to help them. When learners are stuck that's where I do some prompting, asking the questions that will make them see what they are not seeing.

Question 7

In A you see that learners are not being involved like as it is on B. The learners are now involved in the activity. Although the prediction is in both A and B .I feel the learners are more involved in B than they are in A.

Question 9

T: The reason why I have taken C there is that I have minimized guidance there. In these groups they have what they are supposed to be using but I am not telling them in advance what it is about or what they are supposed to focus their attention on. To try and giving them that autonomy in that they will be able to explore and come up with whatever they are going to come up with. At the end they also have to report. As they report their observation, I will be there to help them see how this is similar to something happening on earth

R: In schools do you give them that autonomy.

T: There are many factors that come to play here. It depends on how much time you have and how many learners have. In public school the numbers will not allow that. When it’s easy to set up and to control them sometimes you give them that liberty to set up there apparatus, but it’s not always because you need also to move with your syllabus so that you complete it because this thing will need time so that you can complete it. It needs a lot of time as they explore. They might have one set up and realize it’s not working, they need time to restart, but I always come in and assist to give them direction.

R: If I can split a practical into five steps (i) asking question (ii) planning (iii) conducting experiment (iv) collecting data (v) making sense of results and analysis of data. Which step do you give them freedom?

T: Step 1, 2 and 3 I do not give them full freedom because those are crucial, they need to have direction of where we are going otherwise they will go astray. They can make conclusions which might be right but not leading to the concept that we are looking for. So I would also come in there to try and give some guidance so that we come up with what exactly we are looking for. So I would also come in there to try and give some guidance so that we come up with exactly what we are looking for.

Step 4 and 5. I can leave them to explore, to come up with whatever they come up with. Of course I have given them some direction at the beginning, now they have the results. I want to see how they will conclude I also come in.

R: When you are giving your learners an investigation what are the important steps

T: They must be able to plan and design and they must know where they are getting to come up with the best method that will get them to that stage. They must be able to observe and take measurements. I think it is very important.

R: In the case that you find that they can’t take measurements.

T: I will leave them to do it and see how they do it. Then get where they are getting it wrong. If it is a case that they do not know how to use an instrument, I help them use that instrument so that they know how to use it or they know how to use it but they are taking the readings wrongly. Things like parallax error or human error. I also teach those things so that they know how to do them correctly.

R: What about the Inquiry

T: Usually when we do these practical like CAPS these days they are separating experiments from practical investigations. They say we are doing them to verify. Like verifying Newton” s second law. When we are doing an investigation they say we do not know the law. We want to find out the relationship between any given variables. When I am doing those investigations at the beginning of the year to my grade 10 that’s when we teach them how to construct an investigative question, how to come up with the conclusion. From grade 10 I know I have taught them how to come up with those things .As we go to grade 11 and 12 that’s assumed knowledge. In case they cannot do it I will help them recap what was done in grade 10.In each and every practical they do they must be able to do that.

R: What are some of the challenges you face.

T: In the public school it the issue of the resources versus the number of learners. It’s very difficult if you put them in groups the groups are too big. That would speak of things like discipline and controlling them. In such a situation it becomes difficult. If left to do on their own, the fast one will be doing it alone and others may not be involved.

R: Does the learner ability affect.

T: One must know how to handle the difference

Appendix N: Sample of lesson observation transcripts

Mr. Charles Lesson 6 Grade 11

TOPIC: Newton's Laws (Acceleration versus mass)

The teacher prepared to teach Newton's second law using an experiment where the learners investigated the relationship between mass and acceleration. The learners had investigated the relationship between acceleration and force in their previous lesson and they were now familiar with the equipment. The learners were supposed to design an investigation to find the relationship between acceleration and mass. The teacher provided the learners with all their equipment and ask them to come up with a method and then carry out the experiment. The learners are working in groups of fives and their task is to come up with a method to prove the relationship between acceleration and mass. The learners sit in their groups and started discussions on how to find out the relationship between mass and acceleration. This was a moment of planning required an understanding of the variables at stake. The following excerpt is a conversation between learners in one group.

L1: what are we looking at?
L2: we want to change mass and see how fast the trolley will go.
L3: so what mass are we changing? Is it the mass of the trolley?
L1: Are we allowed to use different trolleys or trolleys of different mass?
L3: we are given only one trolley, then it means we do not have that option.
L2: we can change the mass of the trolley we have.
L4: how? Can we remove some of the mass on it, but how?
L5: I think we can add instead.

The teacher then asked learner 5 what he meant by adding. The learner suggested they add another trolley like what they did in the previous experiment where they added more force through adding the rubber bands. Then, in this case, they were supposed to use more trolleys to increase the mass. The teacher looked at the steps that were listed on their plan and asked some probing questions for them to reconsider some things. The excerpt below is the evidence of the teacher probing the learners for the answers to make their method more plausible.

T: do you think rail can take more than three trolleys?
L: Yes.
T: when they are three what will be the mass of the system?

L: the mass of the three plus the weight pulling them.

T: you do not have such an option because you are given one trolley and some masses over there. Each mass is equivalent to the mass of a trolley. So what do you think?

L: we put the mass on top of the trolley.

T: then?

L: that will be a trolley of different mass.

T: you can proceed and do the experiment.

Mr. Charles moved to the next group that was already performing the experiment. The teacher asked the group members for their plan and checked their plan which to him was perfect. The teacher asked the learners to reduce their angle of inclination, to avoid breaking the trolley when acceleration is too high. The teacher went around all the groups and then asked all the groups to record their information in the table of their choice and use the results to draw a graph of the relationship between acceleration and mass. The learners could easily get the dependent and independent variable. The teacher could probe the learners to figure out the controlled variable. The excerpt below is the evidence of a conversation between one learner and the teacher on the variables.

T: what is the controlled variable in this experiment?

L: mass

T: mass of what?

L: mass of trolley

T: what is it that I want with the rubber band?

L: mass of trolley?

T: then can the same mass be the controlled variable?

L: No

T: What are you keeping constant?

The learners in the group kept quiet, but they had finished the experiment and their results were showing the correct relationship between mass and acceleration. The teacher then asked the learners from each group to come and present their results and conclusion. Each group was supposed to give a description of how they carried out the experiment and the challenges faced.

Mr. Kapok Lesson 8 (Grade 10)

TOPIC: Electricity

The learners enter the laboratory in a rush as the teacher is already waiting for them. The tables are arranged into eight working stations. The learners arranged themselves to fit onto the working stations. The teacher greeted the class and ask them why they did not come early when they are aware that they are having an experiment. The learners told the teacher that they were delayed by the other teacher who finished late. The teacher then went straight into the business of the day. The excerpt below is the teacher's interaction with the class as a whole before they started to work in groups.

> T: we have circuit boards on the table, connecting wires and four cells. Here are worksheets that have the diagrams of the circuits that you must build and measure the voltage and current. Each learner must record the reading on their worksheet and write the names of all the group members. You must be fast.
>
> L: when are we submitting sir?
>
> T: today, you know this? We have done circuits in class before.

The learners collected their worksheets and started their experiment. There was clapping of hands at one group and the teacher went to the group to witness the occasion. The learners had successfully built a circuit and their bulbs are glowing. The following excerpt is the conversation between the teacher and learners in that group.

> T: why is everyone happy in this group?
>
> L: we managed after a struggle to come up with our circuit for parallel resistors.
>
> T: what was the main problem and how did you solve it.
>
> L: we did not know how the ammeter and voltmeter are connected.
>
> T: what happened?
>
> L: we did our research and now it's working.
>
> T: how then do you connect the voltmeter and ammeter?
>
> L: one must be in parallel while one is in series.
>
> T: which one is in parallel?

L: voltmeter

L2: sir, why is the voltmeter not connected in series

L3: it has high resistance, and current won't pass

The teacher visited the next group they had already having readings for the series connection. The teacher asked the leaner of their conclusion from the results. The following is the interaction between the teacher and the learners.

T: what do the results tell you about the resistors in series?

L1: if we measure the current it does not change.

T: okay, what about the voltage?

L2: the voltage is not the same it's changing.

T: what do you mean, use V_1, V_2, $V_{3,}$ and T_{total}.

L3: v_1 and v_2 are different.

T: did you try to add them? Try it.

L4: they give us v_3.

T: what does it mean?

The teacher goes to the next group that had connected well but were struggling with understanding why their voltage is not changing. They thought the voltmeter was not working. The teacher asked them to measure current and they did. The following excerpt is the evidence of the interaction between the teacher and the group members.

L: I think our voltmeter is faulty.

T: why?

L: the voltmeter reading at all the points are the same.

T: is that the only problem? Can you measure current?

L: we did

T: what is the current?

L: Its fine, it's changing.

T: look here if we add this one and this one what does it give us?

L: I can see, current is dividing. It means the voltage must be the same.

T: which connection is that?

L: parallel connection.

The teachers asked the learners to complete the task in the remaining time and submit their papers.

Mr. Moloku Lesson 8 (Grade 10)

TOPIC: Magnetism

T: We want to have a look at magnetism. [*Writing on the board the topic*]

T: What do you understand by that term?

L1: When something has attraction

L2: When a steel gets the properties of magnet.

L3: How does a thing demagnetize.

T: You can use magnet.

T: Magnetism occurs in materials that are ferromagnetic. [*Writing on the board*] We have to write this?

L2: Yes

T: Which two materials or metals use magnetic

L1: Iron and Nickel

L2: Nickel, copper

T: not copper

L3: cobalt

T: These are only two iron and cobalt. They are two only, these ones can result in what are called permanent magnets .Which means we also do have temporary magnets.

L4: It's like sometimes when you take out screw the thing rub on the screw and the thing is magnetic.

T: Yaah

L2: Some of those screw drivers are magnetic.

L1: When a scissors cut staples, the staples start to be attracted to the scissors.

T: it means that scissors is made up of one of these metals and they happen to have those properties.

L1: Is it already diamagnetism.

T: On permanent magnets we have got bar magnets .We also have temporary magnets (writing on the chalkboard). On temporary magnets you gave me e.g. electromagnets they are rare because of electricity, if I take a bar magnet it has the ability to attract any material that is ferrous (that has iron or that has cobalt).That bar magnet has a sphere of influence. There is distance where if you place the material it gets attracted if you continue to increase the distance what happens?

L2: It will no longer be attracted

T: You might reach a point where it's no longer attracted, that region in which a material experience a force of attraction. Let's say in this region if I put an iron it gets attracted but if I go out of the region nothing will happen. This region where this magnet has an influence, what do you call it?

L1: Magnetic field

T: Yes we call that the magnetic field ,just like we have gravitational field ,just like we have electric field .What we want to do today is study the magnetic field around a bar magnet. To represent the magnetic field we use what are called magnetic field lines, just like we have gravitational field lines and just like we have electric field lines. So we want to establish the pattern of magnetic field lines around a magnet. That activity I have given you there. I am not going to tell you what to do, I want you to read instructions and then at the end, I want someone to come and draw the magnetic field lines as from your experiment not from your knowledge. You work in pairs, there is a magnet for each pair you need iron filling and a paper. You haven't read and you are doing it wrongly, read the instructions.

L1: Sir Can I take a picture of this

T: Yes you may.

L1: Yes I want to draw it. [*The learner goes on the chalkboard to draw*], I just going to draw solid lines.

T: Do you know where magnets are ending at the bottom. [*The learner draw his diagram and indicated to the teacher that he had finished*]

T: I am worried about something, your lines.

L2: I know your lines must be [*the teacher stopped the learner and ask him to go and draw his own by the side*]

T: No go and draw your own lines by the side. [*The second learner went to the front and drew their own diagram by the side*]

T: You have a very good outcome there.

L1: It's so cool when you have a metal table and sprinkle the iron fillings on the table and put the magnets under the table. My dad has also strong magnets, the magnets are too strong you have to put a piece of cupboards between the magnets to put them apart.

T: Let's have a look at the two diagrams and what is the difference between these two diagrams? If there is any?

L1: Sans's has more detail

T: The important thing that you must take note of about is where they are starting.

L1: Even the middle of the magnets.

L2: from the pole

T: There are starting from the ends of the magnet.

L2: The poles.

T: Have a look at what you did here, they must come to the ends. [*The teacher say as he make some corrections on the diagram of L1*]. Even this ones they must actually start from here to there .All the lines are starting from here to there.

L2: Sir there is one in the middle of the magnets.

T: Can you trace them carefully and see where they end.

L2: Yes I can see it.

T: No they won't end here, they will all end at the end of the magnets. Have a look at this, why do we have some concentrated here. Why are we not having such here and there? It means the lines are going from here to there.

L2: If you have to lift the paper you will see they will all go to the square. [The learner feels his diagram was correct]

T: There are other ones that are going like that, these two ends that you see on your diagram are called poles. In the next activity we want to see if the poles are the same

L12: There are not obvious.

T: Let's do it now work in groups of four since you need two magnets. Follow the instructions.

L2: There are no instructions

T: They are two of them.

L2: Design and carry out experiment to answer the question, Are the poles the same.

T: Yes I want to see you design your experiments, think as to how you are going to do it.

L2: That makes no sense. Take two magnets and a string

L1: Do we have compass?

T: You don't need a compass for now. You only need two magnets, we want to say are these poles the same, Show me by two magnets.

T: Work together

L2: Do you have a piece of string?

T: Yes I have. You are working together because you only have two magnets.

[*The learners put a retort stand on the table*]

T: You have to show me that they are not the same. You should be working together as a group.

[*The learners put the magnets together*]

T: Why can't you use the string, you were doing the right thing. And you two what are you waiting for?

L1: The magnets

T: You must be working together, put the retort stand in the middle.

[*The learners are tying the magnets in the middle*.]

L2: I will hold the centre of the string.

T: Is that telling you that the poles are not the same.

L2: Yes

T: How?

L1: The opposite poles attract each other.

T: What are you calling North or South Pole?

L2: Because it's written North and South Pole on the magnets

T: If it was not written

L2: I already used it at my dad's workplace.

T: That means the end are not the same .One is called N and the other one is called S and these lines if they don't have arrows like this, they are not complete. They always run from the North to the South. You must put your arrows like that. Now the instruction say, describe what you did, I want you to write a brief description of what you did.

L1: In our books?

T: Yes in your books.

The lesson ends with learners writing in their books.